University of Alberta Library
0 1620 3715373 9
-344

Chemistry 30

Distance Learning

Alberta EDUCATION

Chemistry 30
Student Module
Lessons 1-20
Alberta Correspondence School
ISBN No. 0-7741-0564-X

ALL RIGHTS RESERVED

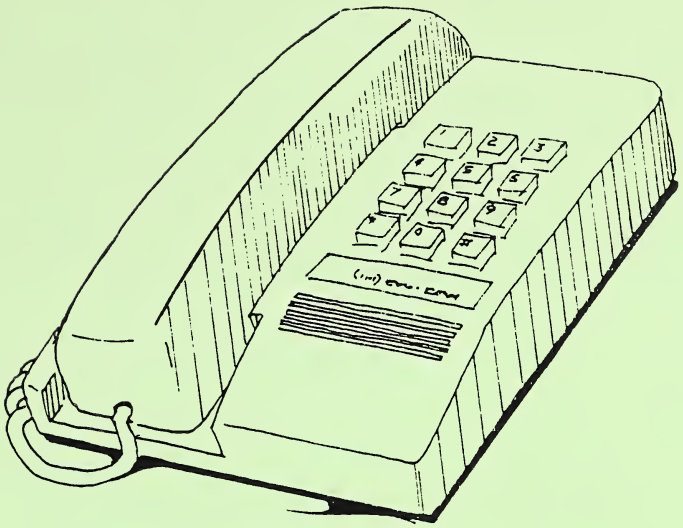
Copyright ® 1990, the Crown in Right of Alberta, as represented by the Minister of Education, Alberta Education 11160 Jasper Avenue, Edmonton, Alberta, T5K 0L2.
All rights reserved. Additional copies may be obtained from the Learning Resources Distributing Centre.

No part of this courseware may be reproduced in any form including photocopying (unless otherwise indicated), without the written permission of Alberta Education.

Every effort has been made both to provide proper acknowledgement of the original source and to comply with copyright law. If cases are identified where this has not been done, please notify Alberta Education so appropriate corrective action can be taken.

UNIVERSITY LIBRARY
UNIVERSITY OF ALBERTA

SPECIAL ASSISTANCE



TOLL FREE

Method 1

1. Look in your local telephone directory under the Government of Alberta for your local **RITE** number.
2. Dial the RITE number.
3. Ask for the Alberta Correspondence School in Barrhead.

NOTE: If there is no local RITE number use the following procedure:

Method 2

1. Dial the Operator (0).
2. Ask for Zenith 22-333.
3. Ask for the Alberta Correspondence School in Barrhead.

Contents of Course

Lesson 1: Review
- A. Math Review
- B. Review of Chemistry 10
- C. Review of Chemistry 20
- D. Significant Digits

Lesson 2: Rates of Chemical Reactions
- A. Introduction
- B. The Nature of Chemical Reactions
- C. Effect of Concentration - Collision Theory
- D. Experiment 1 - A Study of Reaction Rates

Lesson 3: Rates of Chemical Reactions (continued)
- E. Effect of Temperature -Collision Theory
- F. Reaction Mechanisms
- G. The Role of Energy in Reaction Rates
  - (1) Activation Energy
  - (2) Heat of Reaction
  - (3) Action of Catalysts and Some Reaction Mechanisms

Lesson 4: Energy Changes
- A. Introduction
- B. Energy in Phase Changes
- C. Energy in Chemical Reactions

Lesson 5: Energy Changes (continued)
- D. Energy in Chemical Reactions (continued)
  - (1) Enthalpy
  - (2) Experiment 2 - Heat of Reaction

Lesson 6: Energy Changes (continued)
- E. Additivity of Reaction Heats
- F. Conservation of Energy and Comparison of Energy Changes

Lesson 7: Energy Changes (continued)
- G. Energy in Nuclear Reactions

Lesson 8: Energy Changes (continued)

Lesson 9: Chemical Equilibrium
- A. Recognizing Equilibrium
- B. The Dynamic Nature of Equilibrium
- C. Experiment 3 - Qualitative Chemical Equilibrium
- D. Math Review
- E. Effect of Concentration Changes
- F. Effect of Temperature Changes
- G. Effect of Pressure Changes
- H. Effect of a Catalyst in Equilibrium
- I. Le Chatelier's Principle - A Regularity

Lesson 10: Chemical Equilibrium (continued)
J. The Synthesis of Ammonia by the Haber Process and the Production of Diamonds from Graphite
K. The Equilibrium Constant
L. The Law of Chemical Equilibrium
M. Special Cases of Equilibrium Constants
N. Calculation of the Solubility of Silver Chloride in Water
O. The Factors Which Determine Equilibrium
P. Review

Lesson 11: Aqueous Acids and Bases
A. Operational Definitions of Acids and Bases
B. The Arrhenius' Definitions of Acids and Bases
C. Review of Chemical Equilibrium
D. The Neutralization Reaction
E. Experiment 4 - Heat of Acid-Base Reactions
F. The Special Relation of $H^+_{(aq)}$ to $OH^-_{(aq)}$

Lesson 12: Aqueous Acids and Bases (continued)
G. Experiment 5 - A Simple Titration
H. Experiment 6 - More Titrations
I. Acid-Base Titrations

Lesson 13: Aqueous Acids and Bases (continued)
J. The Bronsted-Lowry Definitions of Acids and Bases
K. Experimental Determination of K_A
L. Experiment 7 - Determination of $[H^+]$, using Indicators
M. The Strengths of Acids and Bases

Lesson 14: Aqueous Acids and Bases (continued)
N. The Strengths of Acids and Bases (continued)
O. Calculations of H_3O^+
P. Experiment 8 - Bronsted Acids and Bases
Q. Review

Lesson 15: Oxidation and Reduction
A. Introduction
B. Oxidation Numbers
C. Experiment 9 - Activity of Metals
D. The Chemistry of Electrochemical Cells

Lesson 16: Oxidation and Reduction (continued)
E. Redox Reactions in a Beaker
F. Competition for Electrons
G. Volts, Amperes, and Coulombs
H. The Voltage of an Electrochemical Cell and the Tendency to Accept Electrons
I. Prediction of Redox Reactions
J. Storage Batteries and Electrochemical Cells

Lesson 17: Oxidation and Reduction (continued)
K. Experiment 10 - Corrosion of Iron
L. Corrosion of Iron, an Undesirable Redox Reaction
M. The Electrolytic Process, a Nonspontaneous Redox Reaction
N. Experiment 11 - Relationships Between Moles
O. Quantitative Relations in Electrolysis
P. Balancing Oxidation-Reduction Equations

Lesson 18: Oxidation and Reduction (continued)
Q. Balancing Oxidation-Reduction Reactions (continued)
R. Experiment 12 - Reactions Between Ions in Solution
S. Review of Redox

Lesson 19:
A. Percent Dissociation of Acids
B. pH Values Using Decimals
C. Ranges of Indicator Values
D. Titration With Redox Reactions
E. Redox Electrolysis
F. More on Acid-Base Reactions

Lesson 20: Review
A. Review of Energy Changes
B. Review of Acids and Bases
C. Review of Oxidation and Reduction
D. Review of Rates of Chemical Reactions
E. Review of Chemical Equilibrium

Equipment Needed for Experiments

Those materials with a * are in the kit. The student who has purchased a laboratory kit will be lent a balance, a set of weights, a 10 mL graduated cylinder and a thermometer. The student is expected to obtain the remaining supplies on his own.

Experiment 1 - A Study of Reaction Rates

*corn starch
*8.3 g potassium iodide (KI) for Solution A
*0.20 g sodium thiosulfate ($Na_2S_2O_3 \cdot 5H_2O$) for Solution B
*5.7 g ammonium peroxydisulfate ($(NH_4)_2 S_2O_8$) for Solution C

1 - thermometer (lent)
*2 - 250 mL plastic beakers
1 - 10 mL graduated cylinder (lent)
*1 - stirring rod
tap water
1 tin can (from a vegetable)
1 sweep handle watch (to record seconds)
2 cubes of ice
*2 - 19 × 150 mm test tubes
*1 - eye dropper
3 - containers for solutions (clean jars or styrofoam cups will be satisfactory)
balance (lent)

Experiment 2 - Heat of Reaction

4 g of sodium hydroxide, NaOH, (lye from local store)
200 mL of vinegar, $HC_2H_3O_2$

2 styrofoam cups
*1 - stirring rod
*2 - 250 mL plastic beakers
balance
water
thermometer
10 mL graduated cylinder

Experiment 3 - Qualitative Chemical Equilibrium

*KSCN (10 mg)
*$Fe(NO_3)_3$ (0.50 g)
*Na_2HPO_4 (a few grains)

*1 - 250 mL plastic beaker
*4 - 19 × 150 mm test tubes
*1 - stirring rod
*eye dropper

Experiment 4 - Heat of Acid-Base Reactions

No material is required.

Experiment 5 - A Simple Titration

NaOH (lye from local store)
vinegar (from kitchen)
*phenolphthalein
1 - 10 mL graduated cylinder
*1 - 250 mL graduated plastic beaker
*4 plastic pill cups
plastic spoon
balance
tap water
*stirring rod

Experiment 6 - More Titrations

No material is required.

Experiment 7 - Determination of $[H^+]$, using Indicators

*0.1 M HCl
NaOH (lye)
*phenolphthalein
vinegar
*litmus paper
*orange IV indicator
*methyl orange indicator

labelling tape
1 - 10 mL graduated cylinder
*eye dropper
*test tube stopper for a 19 x 150 mm test tube
*13 plastic pill cups
*2 - 250 mL plastic beakers
*4 - 19 x 150 mm test tubes

Experiment 8 - Bronsted Acids and Bases

No material is required.

Experiment 9 - Activity of Metals

*silver nitrate
*0.1 M HCl (hydrochloric acid)
*copper sulfate
*zinc sulfate
*lead nitrate
*copper pellets
*lead foil
*zinc strips
*steel wool
*iron nail

*11 - plastic pill cups
labelling tape
10 mL graduated cylinder

Experiment 10 - Corrosion of Iron

sodium hydroxide (NaOH)
*sodium carbonate (Na_2CO_3)
*potassium nitrate (KNO_3)
*nitric acid (HNO_3)
*potassium ferricyanide ($K_3Fe(CN)_6$)
*iron II sulfate ($FeSO_4$)
*litmus paper
*1 g agar
*phenolphthalein
*copper wire
*zinc strip
*steel wool
*9 - iron nails

*4 - 19 x 150 mm test tubes
*stirring rod
labelling tape
water
*2 - 250 mL plastic beakers
balance
1 - 10 mL graduated cylinder
*3 pill cups
tin can
pliers
*eye dropper

Experiment 11 - Relationships Between Moles

No material is required.

Experiment 12 - Reactions Between Ions in Solution

*magnesium nitrate ($Mg(NO_3)_2$)
sodium hydroxide (NaOH)
*sodium sulfate (Na_2SO_4)
*iron II sulfate ($FeSO_4$)
*potassium permanganate
*lead nitrate ($Pb(NO_3)_2$)
salt (NaCl)
*potassium iodide (KI)
*sodium sulfide (Na_2S)

10 mL graduated cylinder
water
*10 plastic pill cups

Textbooks:

Chemistry, Experiments and Principles by O'Connor et. al.

Laboratory Manual to above textbook by O'Connor et. al.

General Information

Presently, all Alberta students studying chemistry must take either the Alchem program for Chemistry 10, 20, and 30, or they can use Keys to Chemistry for Chemistry 10 and 20 and the textbook by O'Connor for Chemistry 30. A student should be able to switch from one program to the next without too much difficulty since the same concepts are to be covered in both programs. All chemistry courses have a core of topics which must be covered, and any one of several options can be covered. The "options" in this course are "Rates of Chemical Reactions" and "Chemical Equilibrium". These are probably the most important options for anyone wanting to go to University. The "core" material includes Chemical Energetics, Acids and Bases, and Oxidation-Reduction.

Often, you will be asked to read certain sections of the book. It is important that you read these sections at the time it is indicated. The following write up in the lesson notes are written on the assumption that the textbook was read, and the lesson notes may not make sense on their own. Hopefully, they make sense after you have read the appropriate sections in the textbook! If, after studying the textbook and the lesson notes, something still doesn't make sense, ask about it. If you have a major problem, and don't feel you can do a whole exercise or a major portion of the lesson without getting it cleared up, either phone in (674-5333) or start the next major section (which usually start every four lessons) and ask specific questions you may have on that lesson. We don't want students phoning in twice a day for every little matter, but by the same token, we don't want students to spend twenty hours trying to understand a certain paragraph which may only take ten minutes to clear up by phone. Phone Barrhead using the R.I.T.E. line.

Also, do the exercises which appear in the middle of each chapter in the textbook when they are assigned. If, after checking the answer, and thinking about where you may have gone wrong, the answer at the back still doesn't make sense, ask about it. Later sections may not be as clear if you don't understand how the answers to these exercises were arrived at.

Many of the odd numbered problems in the textbook have answers at the back, although the answers may be wrong in some cases. Many problems in the Lessons are taken right from the textbook, and it would be no problem for you to see which problem in the textbook it corresponds to if you so desire. We assume you have the maturity to realize that merely getting the correct answer to any problem will not enable you to learn chemistry. You should always show your work so we know the steps you followed in getting the answer; this way we can tell exactly where you went wrong. Often students get everything right as far as the chemistry is concerned, but make a simple math error in the last step. However, if just a wrong answer appears, don't expect the teacher to explain all of the possible ways you may have gone wrong. So don't just put the answer down, but feel free to look up the answer after you have solved the problem on your own, as a check on your work.

Final Mark

Your final mark will be determined as follows:

Final Test	- 70% emphasis on core material
All lessons	- 30%

This weighting will be altered only if there is a large discrepancy between your course work and your final mark. That is for the lesson portion to count towards the final grade the student must score at least 40% on the final test. A student who scores less than 40% will receive the test mark as the final grading. Also note that a passing mark of 50% must be obtained to receive credits in the course. You are required to write the Provincial Diploma Examination.

In general, the assessment should not hurt your mark. However, we often have students who can do the most complex problems in the lessons, since they have the answers from a previous student's lessons, but they can't do the simplest problems on a test. There is nothing wrong with getting a bit of help, but be sure you understand what you are doing, so that you could do a similar problem on the test.

The final test is a Closed Book test and it must be written under strict supervision. A Chemistry Data Booklet will be provided during your examination. In making calculations, one can use calculators. For regular school students, principals are in charge of the final test. All questions pertaining to the test arrangements must be directed to him. Non-classroom students must make their arrangements as suggested in the Information Bulletin.

Laboratory Work

The laboratory work is extremely important and the experiments furnish a basis for understanding the concepts of chemistry. When doing laboratory work, prepare yourself thoroughly beforehand so that you know exactly what you are trying to do and how you plan to do it.

Since you are taking this course by correspondence, you will probably be using a lab kit (unless you can use a school lab) which will enable you to do all the required experiments reasonably well. Even with a well equipped school lab, we will just expect you to do what a student can do who has our lab kit.

Since it is impossible to send out all materials which a good school lab has, our procedures are somewhat different from those given in the lab manual. You are advised to read through each experiment in the lab manual since it gives helpful information. This will enable you to understand each lab better. Due to limited lab supplies, do what is indicated in the lesson notes rather than the lab manual and answer questions which are asked for in the lessons.

CAUTION: Do not taste any of the chemicals. Keep them out of the reach of children and away from pets. If a chemical spills on your work surface, your skin, or your clothing, wipe it immediately and rinse with plenty of cool water. Dispose of all chemical solutions in a safe manner after each experiment is finished, but save the unused portions in case they are needed for later experiments. For more information see the portion entitled 'Policy on Handling Chemicals' on the next page.

CAUTION: ONCE AGAIN, TREAT ALL CHEMICALS AS POISONOUS AND AVOID CONTACT WITH SKIN

Please Note

Because of the large demand for our balance sets, some students may not receive their sets in time to do the experiments. We, therefore, suggest that these students do the theory part of the lesson and hold back the entire lesson until they are able to complete all laboratory work and related exercises at a later date when they receive the equipment. Lessons that require no balance sets could be completed in the normal way and sent for correction as soon as they are completed.

Policy on Handling Chemicals

The following information is available to all students enrolled in courses offered by the Alberta Correspondence School which make use of chemicals:

1. A list of chemicals accompanies each laboratory kit that students purchase.

2. A warning notice is provided with each laboratory kit containing chemicals. This notice states that "all chemicals must be regarded as poisonous." On this notice students are informed to:

   a. store all chemicals out of reach of children,

   b. use the chemicals as instructed in the lesson notes, and

   c. dispose of these chemicals promptly after use.

3. The lesson material that deals with handling chemicals contains information as to what students need to do if any of these chemicals are spilled on the work surface or on the skin and clothing.

   In general, if chemicals are spilled on the work surface soak them up with a sponge. Wear safety gloves while doing this procedure. Then dilute with excess water and rinse the chemicals down the drain. Wash the sponge carefully making sure the chemical residues have been washed away. The chemicals contained in each laboratory kit are not likely to damage the work surface (i.e. counter, table); however, it is recommended that students use a thick layer of papertowel or a rubber mat to protect the work surface from any spills that may occur.

   If chemicals come in contact with clothing, remove the clothing immediately and rinse thoroughly with excess water. Wear protective plastic gloves while doing this procedure.

   If the student's hands come into contact with chemicals they are to be washed thoroughly with water and then soap and water.

4. Information regarding the method of disposing of chemicals are included in the introduction of Chemistry 30 as well as within the lessons. In general, liquids and solids are to be diluted with water and flushed down the drain with large quantities of water. These solids and liquids can also be flushed down the toilet where they are automatically diluted. A few of the chemicals found in the lab kit need to be disposed of in a special manner. In these particular cases extra chemicals will be provided in the laboratory kit to safely dispose of these chemicals.

5. It is recommended that students wear plastic gloves, some eye protection (goggles), and some protective clothing (i.e. lab coat or smock) when dealing with chemicals.

6. Washing procedure to be followed if acids and/or alkali (bases) get into the eyes:

   a. **Acids**: wash eyes with cold water for 20 minutes and seek immediate medical attention.

   b. **Bases (Alkali)**: wash eyes with cold water for 25 minutes and seek medical attention immediately.

7. It is imperative that students do all their lab work near the sink or where water is available.

8. Students must remember to wash their hands thoroughly after each experiment.

The following list describes the chemicals used in Chemistry 30, as well as the recommended methods of disposal. Some of these chemicals are used in more than one lab experiment therefore, do not dispose of these chemicals beforehand. Make sure that all experiments which require the use of the same chamical are completed before the chemical is disposed. Refer to the information on this list when you are disposing of these chemicals.

Experiments which use chemicals	Chemical	Description and Use	Is this chemical hazardous?	Method of Disposal
Experiment 1	Ammonium Peroxydisulfate $(NH_4)_2S_2O_8$	- formed by the electrolysis of ammonium sulfate under proper conditions. Used as: 1. bleaching and oxidizing agent 2. in electroplating 3. in photography - 5.7g used	No	- flush down the toilet
Experiment 2 Experiment 5 Experiment 7	Acetic Acid (Vinegar) $(HC_2H_3O_2)$	- 200 ml of vinegar used - mild acid - used in cooking and lab work	No	- flush down the drain with excess water
Experiment 2 Experiment 5 Experiment 7 Experiment 10 Experiment 12	Sodium Hydroxide (NaOH)	- 4 g of NaOH used - lye - formed by reaction of sodium carbonate and calcium hydroxide in water and then separation of the solution and evaporation - used in: 1. the manufacture of soap, rayon, paper, 2. petroleum and vegetable oil refining, 3. the rubber industry, in the textile and tanning industries, 4. preparation of sodium salts	No	- flush down the drain with excess water
Experiment 3	Potassium Thiocyanate (KSCN)	- 10 mg used in the experiment - used as a source of thiocyanate - can be used as a herbicide but this compound is less important now because of the development of other organic herbicides that do not decompose so readily	No	- flush down the toilet
Experiment 3	Iron III Nitrate (Ferric Nitrate) $Fe(NO_3)_3$	- (0.5 g) is used - used in enriching soils	No	- flush down the toilet

Experiments which use chemicals	Chemical	Description and Use	Is this chemical hazardous?	Method of Disposal
	Disodium Hydrogen Phosphate (Na_2HPO_4)	- formed by the reaction of sodium carbonate and phosphoric acid and then evaporating - used in: 1. baking powder, 2. medicine, 3. food processing	No	- flush down the toilet
Experiment 5 Experiment 7	Phenolphthalein Powder	- used in titrations, only 3 drops from an eye dropper is usually sufficient (solution form) - only a tiny pinch of phenolphthalein powder is required to make a solution - acid-base indicators used to indicate the end point of a particular neutralization reaction or indicate the PH value of a system	No	- flush down the toilet
Experiment 7	Orange IV Indicator	- an indicator used to determine the hydronium ion concentration	No	- flush down the toilet
Experiment 7	Methyl Orange Indicator	- an indicator used to determine the hydronium ion concentration	No	- flush down the toilet
Experiment 9	Copper Sulfate ($CuSO_4$)	- only 0.5 g used - blue crystals, moderately soluble in cold water, quite soluble in hot water, very slightly soluble in alcohol - used in copper plating, dyestuff manufacture, water treatment, germicides	No	- flush down the toilet
Experiment 9	Zinc Sulfate ($ZnSO_4$)	- a salt of zinc	No	- flush down the toilet

Experiments which use chemicals	Chemical	Description and Use	Is this chemical hazardous?	Method of Disposal
Experiment 10	Sodium Carbonate (Na_2CO_3)	- soda ash: used in glass making - used in the production of soaps and detergents	No	- Flush down the toilet.
Experiment 10	Potassium Nitrate (KNO_3)	- occurs as thin crusts or as silky crystals - white solid - used as a reagent in organic chemistry reactions	No	- Flush down the toilet.
Experiment 10	Nitric Acid (HNO_3)	- colorless or pale yellow liquid - do not store near HBr or HI - fairly dilute sample is used	No	- dilute with excess running water and throw down the drain Handling: wear safety gloves
Experiment 10	Potassium Ferricyanide ($K_3Fe(CN)_6$)	- found in precious or semi-precious stones	No	- throw in the waste paper basket or down the drain with excess water
Experiment 10	Iron (II) Sulfate ($FeSO_4$)	- solid derivative of iron	No	- throw in the waste paper basket or down the drain with excess water.
Experiment 12	Magnesium Nitrate ($Mg(NO_3)_2$)	- solid (white) - formed by the reaction of magnesium carbonate and nitric acid (HNO_3) - humans consume magnesium - magnesium found in milk of magnesia	No	- throw in the waste paper basket or down the drain with excess water.
Experiment 12	Sodium Sulfate (Na_2SO_4)	- ''salt cake'' - white solid - formed by the reaction of sodium chloride and sulfuric acid upon heating - used in dyeing and the manufacture of glass. - used in the textile and tanning industry	No	- throw in the waste paper basket or down the drain with excess water

Experiments which use chemicals	Chemical	Description and Use	Is this chemical hazardous?	Method of Disposal
Experiment 12	Potassium Permanganate ($KMnO_4$)	- used only 0.01 mol/L - purple solid - formed by oxidation of acidified potassium manganate (alkali) solution with chlorine, and then evaporated - used in: 1. disinfectant and bactericide 2. medicine 3. as an important oxidizing agent in many chemical reactions	No	- throw down the drain with excess water
Experiment 12	Sodium Chloride (NaCl)	- salt	No	- throw down the drain with excess water
Experiment 12	Sodium Sulfide (Na_2S)	- yellow to reddish solid - formed by heating sodium sulfate and carbon at high temperature. - used in: 1. cooking liquor, 2. photography, engraving and lithography 3. organic reactions	No	- throw down the drain with excess water
Experiment 9 Experiment 12	Lead Nitrate $Pb(NO_3)_2$	- white crystals - formed by reaction of lead oxide and nitric acid - decomposes on heating, this leaves lead oxide residue - used in photographic emulsions	Yes	Make a solution of lead nitrate and mix it with a solution of sodium silicate (Na_2SiO_2). After adding the solutions together let them stand for awhile. Take the entire solution and flush it down the toilet where it is automatically diluted.
Experiment 7	Hydrochloric Acid (HCl)	- 0.1 mol/L, a very small concentration of HCl - this concentration is not harmful	No	- dilute with water and throw it down the sink or flush down the toilet

Experiments which use chemicals	Chemical	Description and Use	Is this chemical hazardous?	Method of Disposal
Experiment 1	Sodium Thiosulfate ($Na_2S_2O_3 \bullet 5H_2O$)	- crystalline solid - solid is soluble in H_2O - solid is also soluble in ammonia solutions - formed by the reaction of sodium sulfite solution and sulfur upon warming - used to dissolve silver chloride, bromide, and iodide in photographic "fixing" bath - only 1 g is used	No	- flush down the toilet
Experiment 1 Experiment 12	Potassium Iodide (KI)	- used in photographic emulsions - only 1 g used of this salt - also required by humans when iodine supply in the body becomes too low.	No	- flush down the toilet

General Format for the Diploma Examination

The time allotted for the Chemistry 30 Diploma Examination is $2\frac{1}{2}$ hours. The examination consists of both multiple-choice questions (worth 80% of the total examination mark) and written-response questions (worth 20% of the total examination mark). There are 55 marks for multiple-choice questions and 15 marks for the written-response questions.

In the written-response portion of the examination, the marks assigned to each question are shown in the left-hand column beside each question. In this section you are expected to communicate your answers clearly, showing any steps in the solution. Use annotated sketches or diagrams where appropriate. All answers should reflect the correct number of significant figures in calculations and include appropriate units.

You may bring an approved calculator, and you must bring HB pencils and erasers. The Student Evaluation Branch will provide test booklets, answer sheets, and data booklets. **Notes and textbooks are NOT allowed on this examination.**

On the Chemistry 30 Diploma Examination only the core material is emphasized, as indicated by the following chart:

Content Area	Lesson No.	Emphasis in % of Total Examination Mark
Chemical Energetics	L. 4 - 8, incl.	32
Acids and Bases	L. 11 - 14, incl.	34
Oxidation-Reduction	L. 15 - 19, incl.	34
		100%

As well, the Chemistry 30 Diploma Examination assesses the application of the scientific process skills of predicting, hypothesizing, controlling variables, classifying, interpreting data, observing, inferring, designing experiments, and defining in operational terms, to the extent that pencil-and-paper testing permits.

Note: Certain concepts in chemistry are approached differently in the various prescribed references. The following areas of concern have been noted, and the Student Evaluation Branch will use the guidelines below.

Chemical Energetics: heat of reaction (ΔH) can be calculated from heats of formation or by the addition of equations that include heat terms. Since both methods of calculating ΔH may be tested, they have been incorporated in Lesson 8.

Acids and Bases: The concepts of KA and % reaction can serve the same function in many acid-base calculations. Since both values are given for the acids in the **Chemistry Data Booklet**, the student may use either calculation method in answering acid-base questions. (A copy of the **Chemistry Data Booklet** is enclosed.)

Oxidation-Reduction: Oxidation numbers and half-reactions can each serve to balance redox equations. Both concepts may be tested.

Emphasis Placed on Curriculum Objectives for the Diploma Examination

While all the content of the Chemistry 30 course is deemed important, some concepts are more important than others and this is reflected accordingly for Diploma Examination purposes. The priority ratings are as follows:

CODE:
A - high priority
B - medium priority
C - low priority

CONCEPTS (Subject Matter)

PRIORITY RATING			EMPHASIS IN PER CENT
B	Each substance has a definite and characteristic heat content or enthalpy	1. The enthalpy of a substance is the sum of the kinetic and potential energies of the molecules.	32%
A		2. The heat of formation is the energy required or released as a substance is formed from its elements.	
B	Change in matter involves a change in energy	1. Changes that require energy are endothermic and those that release energy are exothermic.	
B		2. More energy is involved in a nuclear change than in a chemical change, and in general more energy is involved in a chemical change than in a phase change.	
A		3. In a phase, chemical, or nuclear change, the change in energy is the energy of the products less the energy of the reactants.	
A		4. The ΔH of chemical and phase changes is determined calorimetrically.	
B		5. By addition of ΔH values for known reactions, ΔH values for new reactions can be predicted.	
A		6. The amount of energy released or absorbed in a phase, chemical, or nuclear change is related to the number of moles of reactants.	

Program Components (continued)

PRIORITY RATING			EMPHASIS IN PER CENT
B	Acids and bases can be defined in different ways.	1. Acids taste sour, change the color of indicators, etc. Bases taste bitter, change the color of indicators, etc.	
B		2. Acids neutralize bases.	
B		3. Arrhenius defined acids as those substances that increase the $H_3O^+(aq)$ concentration and bases as those that increase the $OH^-(aq)$ concentration.	
A		4. Bronsted and Lowry defined acids as proton donors and bases as proton acceptors.	
A	The relative acidity of a solution can be measured.	1. The strengths of acids and bases vary and are a measure of the equilibrium condition.	
A		2. The pH scale is a measure of the $H_3O^+(aq)$ concentration.	34%
B		3. Indicator color may be used to determine the pH.	
A	Acid-base reactions involve an exchange of protons.	1. An acid-base reaction can be represented by a net ionic equation.	
A		2. The relative strengths of bases can be used to predict the equilibrium conditions.	
A		3. Titration is one of the main techniques used in quantitative measurement of acid-base reaction.	
A		4. The determination of quantitative relationships in acid-base reactions is part of stoichiometry.	
B	Redox reactions involve an exchange of electrons.	1. Oxidation is defined as the loss of electrons. Reduction is defined as the gain of electrons.	
A		2. Oxidizing agents cause oxidation and reducing agents cause reduction to occur.	
A		3. A redox reaction can be represented by a net ionic equation.	
B	In a redox reaction the electron loss and gain must balance	1. Oxidation numbers of half-reactions illustrate the loss and gain of electrons.	
A		2. Oxidation numbers of half-reactions may be used to balance equations.	

Program Components (continued)

PRIORITY RATING			EMPHASIS IN PER CENT
B		3. Titration is one of the main techniques in quantitative measurement of redox reactions.	
A		4. The determination of quantitative relationships in redox reactions is part of stoichiometry.	
B	The electric potential of a redox reaction can be predicted and measured	1. Reduction potentials are relative potentials of reduction half-reaction.	
C		2. Oxidation potentials are negative reduction potentials.	
A		3. The relative strengths of oxidizing and reducing agents are compared in terms of a table of reduction potentials.	34%
A		4. The net potential of a redox reaction is the sum of the oxidation and reduction potentials.	
A		5. The spontaneity of a redox reaction can be predicted from the relative strengths of the oxidizing agents or from the positive sign of the net potentials.	
A	Redox reactions involve electrical energy	1. Electrochemical cells convert chemical energy to electrical energy.	
A		2. Electrolytic cells are used to convert electrical energy to chemical energy.	
B		3. There are many applications of electrochemical and electrolytic cells.	

YOUR PERSONAL GUIDE FOR LESSON COMPLETION

In order to ensure that you finish your correspondence course on schedule, without having to send too many lessons at one time, it is important that you devise your own guidelines for lesson submission.

By filling in the blanks below, you can arrive at your own schedule for lesson completion.

1. What is today's date? _____

2. On what date do you need (or want) to finish the last lesson? _____

   (If you wish to write the test at the end of the first semester, your last lesson should be sent during the first week of January.

   If you wish to write in June, your last lesson should be sent during the last week of May.)

3. Using a calendar, count the number of weeks between today and the day you plan to finish your lessons.

   Number of weeks: _____

4. To convert to the number of days, multiply by 7, since there are 7 days in one week.

   Number of Weeks × 7 = _____ days

5. Now calculate the number of days you can spend on each lesson.

   $$\frac{\text{Number of Days}}{\text{Number of lessons to do}} = \frac{\text{days}}{\text{lessons}} = _____$$

   Delete any decimal portion in your final result. (For example, if your answer is 6.5 days for each lesson, only allow 6 days rather than 7. If you were to use 7 days for each lesson, your finishing date would be after your target date. By using 6 days, you allow extra time for review.)

6. Now use the number of days per lesson you calculated above to fill in the date each lesson should be completed in the chart on the reverse side. (The easiest way is to count off the days on a calendar.)

Lesson Number	To be completed by:	Completed
	Today's date:	
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
11		
12		
13		
14		
15		
16		
17		
18		
19		
20		

Check off each lesson as you complete it. Note whether or not you are meeting your target dates. If you find you are getting too far off schedule, you may have to revise your dates.

Use the chart on the next page to provide a copy for your correspondence teacher.

NAME: _____ File #: _____

Now copy your schedule into the chart below and send this sheet in with Lesson 1. By having this timetable, your teacher will know how you plan to work on this course.

Lesson Number	To be completed by:	Completed
	Today's date:	
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
11		
12		
13		
14		
15		
16		
17		
18		
19		
20		

Periodic Table of Elements

TABLE OF COMPLEX IONS

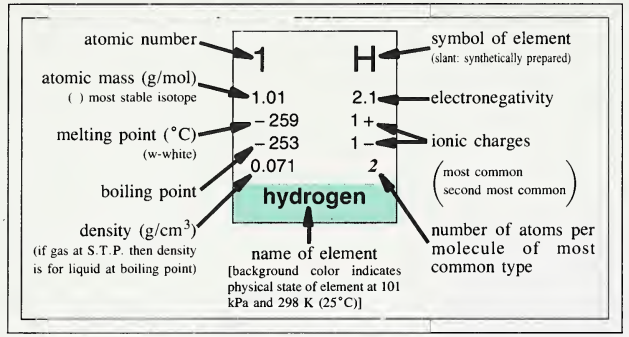
acetate	CH_3COO^-	glutamate	$C_5H_8NO_4^-$
ammonium	NH_4^+	hydrogen phosphate	HPO_4^{2-}
benzoate	$C_6H_5COO^-$	hydroxide	OH^-
bicarbonate (hydrogen carbonate)	HCO_3^-	hypochlorite	ClO^-
bisulfate (hydrogen sulfate)	HSO_4^-	iodate	IO_3^-
bisulfide (hydrogen sulfide)	HS^-	nitrate	NO_3^-
bisulfite (hydrogen sulfite)	HSO_3^-	nitrite	NO_2^-
borate	BO_3^{3-}	oxalate	$OOCCOO^{2-}$
bromate	BrO_3^-	perchlorate	ClO_4^-
carbonate	CO_3^{2-}	permanganate	MnO_4^-
chlorate	ClO_3^-	phosphate	PO_4^{3-}
chlorite	ClO_2^-	silicate	SiO_3^{2-}
chromate	CrO_4^{2-}	stearate	$C_{17}H_{35}COO^-$
cyanide	CN^-	sulfate	SO_4^{2-}
dichromate	$Cr_2O_7^{2-}$	sulfite	SO_3^{2-}
dihydrogen phosphate	$H_2PO_4^-$	tetraborate	$B_4O_7^{2-}$
ferricyanide	$Fe(CN)_6^{3-}$	thiocyanate	SCN^-
ferrocyanide	$Fe(CN)_6^{4-}$	thiosulfate	$S_2O_3^{2-}$
		tripolyphosphate	$P_3O_{10}^{5-}$

SOLUBILITY OF SOME IONIC COMPOUNDS IN WATER AT 298 K (25°C)

ION	Group IA: alkali metal ions	Group IA: H^+ (H_3O^+)	NH_4^+	NO_3^-	CH_3COO^-	Cl^- Br^- I^-	SO_4^{2-}	S^{2-}	OH^-	PO_4^{3-} SO_3^{2-} CO_3^{2-}
SOLUBILITY >0.1 mol/L (VERY SOLUBLE)	All	All	All	All	Most	Most	Most	Group IA Group IIA NH_4^+	Group IA NH_4^+ Sr^{2+} Ba^{2+} Tl^+	Group IA NH_4^+
SOLUBILITY <0.1 mol/L (SLIGHTLY SOLUBLE)	None	None	None	None	Ag^+	Ag^+ Pb^{2+} Hg_2^{2+} Cu^+ Tl^+	Ca^{2+} Sr^{2+} Ba^{2+} Ra^{2+} Ag^+ Pb^{2+}	Most	Most	Most

Periodic Table of Elements

KEY



elements do not form ionic compounds

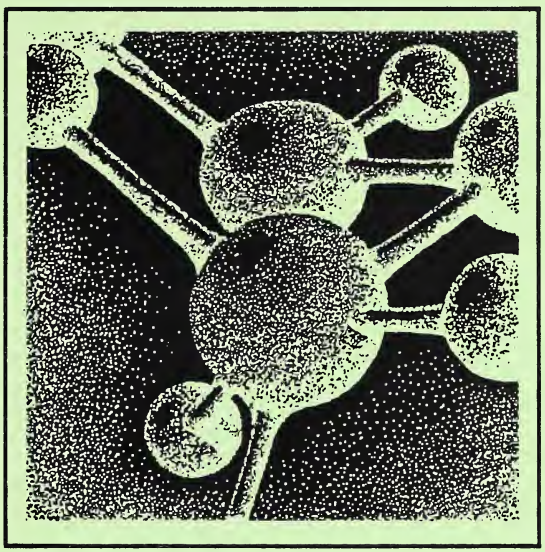
gas

liquid

solid

GROUP IA	IIA	IIIB	IVB	VB	VIB	VIIB	VIIIB			IB	IIB	IIIA	IVA	VA	VIA	VIIA	VIIIA
1 H 1.01 2.1 – 259 1+ – 253 1– 0.071 2 hydrogen																	2 He 4.00 – – 272 – 269 0.126 helium
3 Li 6.94 1.0 180 1+ 1347 0.53 lithium	4 Be 9.01 1.5 1278 2+ 2970 1.85 beryllium											5 B 10.81 2.0 2079 2550 2.34 boron	6 C 12.01 2.5 3550 4827 2.26 carbon	7 N 14.01 3.0 – 210 3– – 196 0.81 2 nitrogen	8 O 16.00 3.5 – 218 2– – 183 1.14 2 oxygen	9 F 19.00 4.0 – 220 1– – 188 1.505 2 fluorine	10 Ne 20.18 – – 249 – 246 1.20 neon
11 Na 22.99 0.9 97.8 1+ 883 0.97 sodium	12 Mg 24.31 1.2 649 2+ 1090 1.74 magnesium											13 Al 26.98 1.5 660 3+ 2467 2.70 aluminum	14 Si 28.09 1.8 1410 2355 2.33 silicon	15 P 30.97 2.1 44.1 w 3– 280 w 1.82 w 4 phosphorus	16 S 32.06 2.5 113 2– 445 2.07 8 sulfur	17 Cl 35.45 3.0 – 101 1– – 35 1.56 2 chlorine	18 Ar 39.95 – – 189 – 186 1.40 argon
19 K 39.10 0.8 63.7 1+ 774 0.86 potassium	20 Ca 40.08 1.0 839 2+ 1484 1.55 calcium	21 Sc 44.96 1.3 1541 3+ 2831 3.0 scandium	22 Ti 47.90 1.5 1660 4+ 3287 3+ 4.54 titanium	23 V 50.94 1.6 1890 5+ 3380 4+ 6.1 vanadium	24 Cr 52.00 1.6 1857 3+ 2672 2+ 7.19 chromium	25 Mn 54.94 1.5 1245 2+ 1962 4+ 7.43 manganese	26 Fe 55.85 1.8 1535 3+ 2750 2+ 7.87 iron	27 Co 58.93 1.8 1495 2+ 2870 3+ 8.9 cobalt	28 Ni 58.71 1.8 1453 2+ 2732 3+ 8.9 nickel	29 Cu 63.55 1.9 1083 2+ 2567 1+ 8.96 copper	30 Zn 65.38 1.6 420 2+ 907 7.13 zinc	31 Ga 69.74 1.6 29.8 3+ 2403 5.90 gallium	32 Ge 72.59 1.8 937 4+ 2830 5.32 germanium	33 As 74.92 2.0 – 3– 615 5.73 arsenic	34 Se 78.96 2.4 217 2– 685 4.79 selenium	35 Br 79.90 2.8 – 7.2 1– 58 3.12 2 bromine	36 Kr 83.80 – – 157 – 152 2.41 krypton
37 Rb 85.47 0.8 38.9 1+ 688 1.53 rubidium	38 Sr 87.62 1.0 769 2+ 1384 2.5 strontium	39 Y 88.91 1.3 1522 3338 4.47 yttrium	40 Zr 91.22 1.4 1852 4377 6.51 zirconium	41 Nb 92.91 1.6 2468 4742 8.6 niobium	42 Mo 95.94 1.8 2617 4612 10.2 molybdenum	43 *Tc* 98.91 1.9 2172 4877 11.5 technetium	44 Ru 101.07 2.2 2310 3900 12.4 ruthenium	45 Rh 102.91 2.2 1966 3727 12.4 rhodium	46 Pd 106.40 2.2 1552 2+ 3140 4+ 12.0 palladium	47 Ag 107.87 1.9 962 1+ 2212 10.5 silver	48 Cd 112.41 1.7 321 2+ 765 8.65 cadmium	49 In 114.82 1.7 157 3+ 2080 7.31 indium	50 Sn 118.69 1.8 232 4+ 2270 2+ 7.31 tin	51 Sb 121.75 1.9 631 3+ 1750 5+ 6.70 antimony	52 Te 127.60 2.1 450 2– 990 6.24 tellurium	53 I 126.90 2.5 114 1– 184 4.93 2 iodine	54 Xe 131.30 – – 111 – 108 3.52 xenon
55 Cs 132.91 0.7 28.4 1+ 678 1.90 cesium	56 Ba 137.33 0.9 725 2+ 1640 3.5 barium	57 La 138.91 1.1 921 3457 6.15 lanthanum	72 Hf 178.49 1.3 2227 4602 13.3 hafnium	73 Ta 180.95 1.5 2996 5425 16.7 tantalum	74 W 183.85 1.7 3410 5660 19.3 tungsten	75 Re 186.21 1.9 3180 5627 21.0 rhenium	76 Os 190.20 2.2 3045 5027 22.6 osmium	77 Ir 192.22 2.2 2410 4130 22.5 iridium	78 Pt 195.09 2.2 1772 4+ 3827 2+ 21.5 platinum	79 Au 196.97 2.4 1064 3+ 2807 1+ 19.3 gold	80 Hg 200.59 1.9 – 39.0 2+ 357 1+ 13.6 mercury	81 Tl 204.37 1.8 304 1+ 1457 3+ 11.85 thallium	82 Pb 207.19 1.8 328 2+ 1740 4+ 11.4 lead	83 Bi 208.98 1.9 271 3+ 1560 5+ 9.8 bismuth	84 Po (209) 2.0 254 2+ 962 4+ (9.2) polonium	85 At (210) 2.2 302 1– 373 – 2 astatine	86 Rn (222) – – 71 – 62 4.4 radon
87 Fr (223) 0.7 (27) 1+ (677) 2.4 francium	88 Ra 226.03 0.9 700 2+ 1140 5.0 radium	89 Ac (227) 1.1 1050 3+ 3200 10.07 actinium	104 (261) Rf rutherfordium Ku kurchatovium	105 (262) Ha hahnium Nl nielsbohrium	106 (263)												

58 Ce 140.12 1.1 799 3+ 3426 6.67 cerium	59 Pr 140.91 1.1 931 3+ 3512 6.77 praseodymium	60 Nd 144.24 1.2 1021 3+ 3068 7.00 neodymium	61 *Pm* (145) – 1080 3+ 2460 7.22 promethium	62 Sm 150.35 1.2 1077 3+ 1791 7.52 samarium	63 Eu 151.96 – 822 3+ 1597 2+ 5.24 europium	64 Gd 157.25 1.1 1313 3+ 3266 7.90 gadolinium	65 Tb 158.93 1.2 1356 3+ 3123 8.23 terbium	66 Dy 162.50 – 1412 3+ 2562 8.55 dysprosium	67 Ho 164.93 1.2 1474 3+ 2695 8.80 holmium	68 Er 167.26 1.2 159 3+ 2863 9.07 erbium	69 Tm 168.93 1.2 1545 3+ 1947 9.32 thulium	70 Yb 173.04 1.1 819 3+ 1194 6.97 ytterbium	71 Lu 174.97 1.2 1663 3+ 3395 9.84 lutetium
90 Th 232.04 1.3 1750 4+ 4790 11.7 thorium	91 Pa 231.04 1.5 <1800 5+ – 15.4 protactinium	92 U 238.03 1.7 1132 6+ 3818 4+ 19.1 uranium	93 *Np* 237.05 1.3 640 5+ 3902 19.5 neptunium	94 *Pu* (244) 1.3 641 4+ 3232 6+ – plutonium	95 *Am* (243) 1.3 994 3+ 2607 13.7 americium	96 *Cm* (247) – 1340 3+ – – curium	97 *Bk* (247) – – 3+ – 14 berkelium	98 *Cf* (251) – – 3+ – – californium	99 *Es* (254) – – – – einsteinium	100 *Fm* (257) – – – – fermium	101 *Md* (256) – – – – mendelevium	102 *No* (259) – – – – nobelium	103 *Lr* (257) – – – – lawrencium



CHEMISTRY
DATA BOOKLET

(Revised)

Alberta
EDUCATION

This Chemistry Data Booklet is similar to the one that will be supplied for your Chemistry 30 Diploma Examination. To become more familiar with its contents you may use this data booklet when doing your correspondence lessons.

Take special note of the Tables on pages 3 and 4 of this booklet, showing Standard Heats of Formation. You will observe that the heat terms are in kJ/mol and that ΔH may be positive or negative in value. The meaning of all this is explained in Lesson 8. Your table in the textbook on page 228 shows kcal and heat terms as part of the equation. Should you need to change kcal to kJ you could multiply the former by 4.19 to get an approximate equivalent in kJ.

Also note that the heat of formation of a compound refers to the energy change involved in the reaction in which that compound is formed from its constituent elements.

For example, the heat of formation of ethanol - $C_2H_5OH_{(\ell)}$ can be written in equation form as follows:

$$2C + 3H_2 + \frac{1}{2}O_2 \rightarrow C_2H_5OH_{(\ell)}$$

$$\Delta H = -277.6 \text{ kJ/mol}$$

You will also recall from reading your supplement that the negative value for ΔH means that the reaction is exothermic.

The table on page 10 of your Data Booklet gives a summary of identical information that is found in your textbook on page 113 Table 6-2.

The Chemistry 30 Diploma Examination is CLOSED-BOOK. However, you will be given a Chemistry Data Booklet to use during the examination and it would be to your advantage to be familiar with it.

CHEMISTRY

MISCELLANEOUS

$H_2O(s) \longrightarrow H_2O(l)$ $\quad \Delta H = +6.03$ kJ

$H_2O(l) \longrightarrow H_2O(g)$ $\quad \Delta H = +40.8$ kJ

Room temperature = 298 K (25°C)

Standard pressure = 101 kPa

The Avogadro number (N_A) = 6.02×10^{23}/mol

Ion product for water (K_w) = 1.00×10^{-14} mol^2/L^2

Specific heat capacities:

$H_2O(s) = +2.01$ J/(g•°C)
$H_2O(l) = +4.19$ J/(g•°C)
$H_2O(g) = +2.01$ J/(g•°C)

Speed of light (c) = 3.00×10^8 m/s

Charge of 1.00 mol of electrons = 9.65×10^4 C

STANDARD HEATS OF FORMATION

NAME	FORMULA	ΔH_f° (kJ/mol)
aluminum oxide	$Al_2O_3(s)$	−1669.8
ammonia	$NH_3(g)$	−46.2
ammonium chloride	$NH_4Cl(s)$	−315.4
ammonium nitrate	$NH_4NO_3(s)$	−365.1
barium carbonate	$BaCO_3(s)$	−1218.8
barium chloride	$BaCl_2(s)$	−860.1
barium hydroxide	$Ba(OH)_2(s)$	−946.4
barium oxide	$BaO(s)$	−558.1
barium sulphate	$BaSO_4(s)$	−1465.2
benzene	$C_6H_6(g)$	+82.9
butane	$C_4H_{10}(g)$	−124.7
calcium carbonate	$CaCO_3(s)$	−1206.9
calcium chloride	$CaCl_2(s)$	−795.0
calcium hydroxide	$Ca(OH)_2(s)$	−986.6
calcium oxide	$CaO(s)$	−635.5
calcium sulphate	$CaSO_4(s)$	−1432.7
carbon dioxide	$CO_2(g)$	−393.5
carbon monoxide	$CO(g)$	−110.5
chromium(III) oxide	$Cr_2O_3(s)$	−1128.4
copper(I) oxide	$Cu_2O(s)$	−166.7
copper(II) oxide	$CuO(s)$	−155.2
copper(II) sulphate	$CuSO_4(s)$	−769.9
copper(II) sulphide	$CuS(s)$	−48.5
ethane	$C_2H_6(g)$	−84.7
ethanoic acid (acetic acid)	$CH_3COOH(l)$	−487.0
ethanol	$C_2H_5OH(l)$	−277.6
ethene (ethylene)	$C_2H_4(g)$	+52.3
ethyne (acetylene)	$C_2H_2(g)$	+226.7
glucose	$C_6H_{12}O_6(s)$	−1273.1
hydrogen bromide	$HBr(g)$	−36.2
hydrogen chloride	$HCl(g)$	−92.3
hydrogen fluoride	$HF(g)$	−286.6
hydrogen iodide	$HI(g)$	+25.9
hydrogen peroxide	$H_2O_2(l)$	−187.6
hydrogen sulphide	$H_2S(g)$	−20.1
iron(III) oxide	$Fe_2O_3(s)$	−822.2
iron(II, III) oxide (magnetite)	$Fe_3O_4(s)$	−1117.1
lead(II) bromide	$PbBr_2(s)$	−277.0
lead(II) chloride	$PbCl_2(s)$	−359.2
lead(II) oxide	$PbO(s)$	−217.9
lead(IV) oxide	$PbO_2(s)$	−276.6
magnesium carbonate	$MgCO_3(s)$	−1112.9
magnesium chloride	$MgCl_2(s)$	−641.8
magnesium hydroxide	$Mg(OH)_2(s)$	−924.7
magnesium oxide	$MgO(s)$	−601.8
magnesium sulphate	$MgSO_4(s)$	−1278.2

STANDARD HEATS OF FORMATION (continued)

NAME	FORMULA	ΔH_f° (kJ/mol)
manganese(II) oxide	$MnO_{(s)}$	−384.9
manganese(IV) oxide	$MnO_{2(s)}$	−520.9
mercury(II) oxide	$HgO_{(s)}$	−90.7
mercury(II) sulphide	$HgS_{(s)}$	−58.2
methanal (formaldehyde)	$CH_2O_{(g)}$	−115.9
methane	$CH_{4(g)}$	−74.8
methanoic acid (formic acid)	$HCOOH_{(l)}$	−409.2
methanol	$CH_3OH_{(l)}$	−238.6
nickel(II) oxide	$NiO_{(s)}$	−244.3
nitric acid	$HNO_{3(l)}$	−173.2
nitrogen dioxide	$NO_{2(g)}$	+33.8
nitrogen monoxide	$NO_{(g)}$	+90.4
octane	$C_8H_{18(l)}$	−208.4
pentane	$C_5H_{12(l)}$	−146.4
phosphorus pentachloride	$PCl_{5(g)}$	−398.9
phosphorus trichloride	$PCl_{3(g)}$	−306.4
potassium bromide	$KBr_{(s)}$	−392.2
potassium chlorate	$KClO_{3(s)}$	−391.2
potassium chloride	$KCl_{(s)}$	−435.9
potassium hydroxide	$KOH_{(s)}$	−425.8
propane	$C_3H_{8(g)}$	−103.8
silicon dioxide	$SiO_{2(s)}$	−859.4
silver bromide	$AgBr_{(s)}$	−99.5
silver chloride	$AgCl_{(s)}$	−127.0
silver iodide	$AgI_{(s)}$	−62.4
sodium bromide	$NaBr_{(s)}$	−359.9
sodium chloride	$NaCl_{(s)}$	−411.0
sodium hydroxide	$NaOH_{(s)}$	−426.7
sodium iodide	$NaI_{(s)}$	−288.0
sucrose	$C_{12}H_{22}O_{11(s)}$	−2225.6
sulphur dioxide	$SO_{2(g)}$	−296.9
sulphuric acid	$H_2SO_{4(l)}$	−811.3
sulphur trioxide	$SO_{3(g)}$	−395.2
tin(II) chloride	$SnCl_{2(s)}$	−349.8
tin(IV) chloride	$SnCl_{4(l)}$	−545.2
tin(II) oxide	$SnO_{(s)}$	−286.2
tin(IV) oxide	$SnO_{2(s)}$	−580.7
water (liquid)	$H_2O_{(l)}$	−285.9
water (vapor)	$H_2O_{(g)}$	−241.8
zinc oxide	$ZnO_{(s)}$	−348.0
zinc sulphide	$ZnS_{(s)}$	−202.9

NOTES: 1. All heats of formation are measured at 298 K (25°C) and 101 kPa.
2. Molar heats of formation for elements in their naturally occurring form are assumed to be zero.

ACID-BASE INDICATORS AT 298 K (25°C)

INDICATOR	pH RANGE	COLOR CHANGE AS pH INCREASES
methyl violet	0.0 - 1.6	yellow to blue
thymol blue	1.2 - 2.8	red to yellow
orange IV	1.4 - 2.8	red to yellow
methyl orange	3.2 - 4.4	red to yellow
bromocresol green	3.8 - 5.4	yellow to blue
methyl red	4.8 - 6.0	red to yellow
chlorophenol red	5.2 - 6.8	yellow to red
bromothymol blue	6.0 - 7.6	yellow to blue
phenol red	6.6 - 8.0	yellow to red
phenolphthalein	8.2 - 10.0	colorless to pink
thymolphthalein	9.4 - 10.6	colorless to blue
alizarin yellow R	10.1 - 12.0	yellow to red
indigo carmine	11.4 - 13.0	blue to yellow
1, 3, 5-trinitrobenzene	12.0 - 14.0	colorless to orange

RELATIVE STRENGTHS OF ACIDS AND BASES

% REACTION WITH WATER	ACID NAME	ACID FORMULA	CONJUGATE BASE	K_a
100	perchloric acid	$HClO_4(aq)$	$ClO_4^-(aq)$	very large
100	hydroiodic acid	$HI(aq)$	$I^-(aq)$	very large
100	hydrobromic acid	$HBr(aq)$	$Br^-(aq)$	very large
100	hydrochloric acid	$HCl(aq)$	$Cl^-(aq)$	very large
100	nitric acid	$HNO_3(aq)$	$NO_3^-(aq)$	large
100	sulphuric acid	$H_2SO_4(aq)$	$HSO_4^-(aq)$	large
100	hydronium ion	$H_3O^+(aq)$	$H_2O(l)$	—
53	oxalic acid	$HOOCCOOH(aq)$	$HOOCCOO^-(aq)$	5.9×10^{-2}
32	*sulphurous acid($SO_2 + H_2O$)	$H_2SO_3(aq)$	$HSO_3^-(aq)$	1.5×10^{-2}
29	hydrogen sulphate ion	$HSO_4^-(aq)$	$SO_4^{2-}(aq)$	1.2×10^{-2}
24	phosphoric acid	$H_3PO_4(aq)$	$H_2PO_4^-(aq)$	7.5×10^{-3}
6.8	**nitrous acid	$HNO_2(aq)$	$NO_2^-(aq)$	4.6×10^{-4}
5.9	hydrofluoric acid	$HF(aq)$	$F^-(aq)$	3.5×10^{-4}
4.2	methanoic acid	$HCOOH(aq)$	$HCOO^-(aq)$	1.8×10^{-4}
—	methyl orange	$HMo(aq)$	$Mo^-(aq)$	$\sim 10^{-4}$
2.5	benzoic acid	$C_6H_5COOH(aq)$	$C_6H_5COO^-(aq)$	6.5×10^{-5}
2.5	hydrogen oxalate ion	$HOOCCOO^-(aq)$	$OOCCOO^{2-}(aq)$	6.4×10^{-5}
1.3	ethanoic (acetic) acid	$CH_3COOH(aq)$	$CH_3COO^-(aq)$	1.8×10^{-5}
0.21	carbonic acid($CO_2 + H_2O$)	$H_2CO_3(aq)$	$HCO_3^-(aq)$	4.3×10^{-7}
—	bromothymol blue	$HBb(aq)$	$Bb^-(aq)$	$\sim 10^{-7}$
0.10	*hydrogen sulphite ion	$HSO_3^-(aq)$	$SO_3^{2-}(aq)$	1.0×10^{-7}
9.5×10^{-2}	hydrosulphuric acid	$H_2S(aq)$	$HS^-(aq)$	9.1×10^{-8}
7.9×10^{-2}	dihydrogen phosphate ion	$H_2PO_4^-(aq)$	$HPO_4^{2-}(aq)$	6.2×10^{-8}
5.4×10^{-2}	*hypochlorous acid	$HOCl(aq)$	$OCl^-(aq)$	3.0×10^{-8}
—	phenolphthalein	$HPh(aq)$	$Ph^-(aq)$	$\sim 10^{-9}$
8.5×10^{-3}	boric acid	$H_3BO_3(aq)$	$H_2BO_3^-(aq)$	7.3×10^{-10}
7.5×10^{-3}	ammonium ion	$NH_4^+(aq)$	$NH_3(aq)$	5.6×10^{-10}
7.0×10^{-3}	hydrocyanic acid	$HCN(aq)$	$CN^-(aq)$	4.9×10^{-10}
2.4×10^{-3}	hydrogen carbonate ion	$HCO_3^-(aq)$	$CO_3^{2-}(aq)$	5.6×10^{-11}
3.3×10^{-4}	hydrogen sulphide ion	$HS^-(aq)$	$S^{2-}(aq)$	1.1×10^{-12}
1.5×10^{-4}	*hydrogen phosphate ion	$HPO_4^{2-}(aq)$	$PO_4^{3-}(aq)$	2.2×10^{-13}
1.8×10^{-7}	water (55.5 mol/L)	$H_2O(l)$	$OH^-(aq)$	1.0×10^{-14}
0	hydroxide ion	$OH^-(aq)$	$O^{2-}(aq)$	very small

INCREASING ACID STRENGTH

INCREASING BASE STRENGTH

NOTE: Unless otherwise indicated, all measurements are made at 298 K (25°C) with acid concentrations of 0.10 mol/L (except for indicators, which are not normally used at that high a concentration).

* Temperature = 291 K (18°C)

** Temperature = 285.5 K (12.5°C)

TWO PLACE LOGS

NO.	LOG	NO.	LOG	NO.	LOG	NO.	LOG	NO.	LOG
1.0	0.00	3.0	0.48	5.0	0.70	7.0	0.85	9.0	0.95
1.1	0.04	3.1	0.49	5.1	0.71	7.1	0.85	9.1	0.96
1.2	0.08	3.2	0.51	5.2	0.72	7.2	0.86	9.2	0.96
1.3	0.11	3.3	0.52	5.3	0.72	7.3	0.86	9.3	0.97
1.4	0.15	3.4	0.53	5.4	0.73	7.4	0.87	9.4	0.97
1.5	0.18	3.5	0.54	5.5	0.74	7.5	0.88	9.5	0.98
1.6	0.20	3.6	0.56	5.6	0.75	7.6	0.88	9.6	0.98
1.7	0.23	3.7	0.57	5.7	0.76	7.7	0.89	9.7	0.99
1.8	0.26	3.8	0.58	5.8	0.76	7.8	0.89	9.8	0.99
1.9	0.28	3.9	0.59	5.9	0.77	7.9	0.90	9.9	1.00
2.0	0.30	4.0	0.60	6.0	0.78	8.0	0.90	1.00	0.00
2.1	0.32	4.1	0.61	6.1	0.79	8.1	0.91	1.01	0.00
2.2	0.34	4.2	0.62	6.2	0.79	8.2	0.91	1.02	0.01
2.3	0.36	4.3	0.63	6.3	0.80	8.3	0.92	1.03	0.01
2.4	0.38	4.4	0.64	6.4	0.81	8.4	0.92	1.04	0.02
2.5	0.40	4.5	0.65	6.5	0.81	8.5	0.93	1.05	0.02
2.6	0.41	4.6	0.66	6.6	0.82	8.6	0.93	1.06	0.03
2.7	0.43	4.7	0.67	6.7	0.83	8.7	0.94	1.07	0.03
2.8	0.45	4.8	0.68	6.8	0.83	8.8	0.94	1.08	0.03
2.9	0.46	4.9	0.69	6.9	0.84	8.9	0.95	1.09	0.04

STANDARD ELECTRODE POTENTIALS

INCREASING STRENGTH OF OXIDIZING AGENTS

INCREASING STRENGTH OF REDUCING AGENTS

Reduction Half-Reaction	$E°$ (V)
$F_2(g) + 2e^- \rightarrow 2F^-(aq)$	+2.87
$PbO_2(s) + SO_4^{2-}(aq) + 4H^+(aq) + 2e^- \rightarrow PbSO_4(s) + 2H_2O(l)$	+1.68
$MnO_4^-(aq) + 8H^+(aq) + 5e^- \rightarrow Mn^{2+}(aq) + 4H_2O(l)$	+1.49
$Au^{3+}(aq) + 3e^- \rightarrow Au(s)$	+1.42
$Cl_2(g) + 2e^- \rightarrow 2Cl^-(aq)$	+1.36
$Cr_2O_7^{2-}(aq) + 14H^+(aq) + 6e^- \rightarrow 2Cr^{3+}(aq) + 7H_2O(l)$	+1.33
$O_2(g) + 4H^+(aq) + 4e^- \rightarrow 2H_2O(l)$	+1.23
$MnO_2(s) + 4H^+(aq) + 2e^- \rightarrow Mn^{2+}(aq) + 2H_2O(l)$	+1.21
$Br_2(l) + 2e^- \rightarrow 2Br^-(aq)$	+1.07
$AuCl_4^-(aq) + 3e^- \rightarrow Au(s) + 4Cl^-(aq)$	+0.99
$NO_3^-(aq) + 4H^+(aq) + 3e^- \rightarrow NO(g) + 2H_2O(l)$	+0.96
$2Hg^{2+}(aq) + 2e^- \rightarrow Hg_2^{2+}(aq)$	+0.91
$Hg^{2+}(aq) + 2e^- \rightarrow Hg(l)$	+0.85
$^1/_2O_2(g) + 2H^+(aq)(1.0 \times 10^{-7}\ \frac{mol}{L}) + 2e^- \rightarrow H_2O(l)$	+0.82
$NO_3^-(aq) + 2H^+(aq) + e^- \rightarrow NO_2(g) + H_2O(l)$	+0.81
$Ag^+(aq) + e^- \rightarrow Ag(s)$	+0.80
$Hg_2^{2+}(aq) + 2e^- \rightarrow 2Hg(l)$	+0.80
$Fe^{3+}(aq) + e^- \rightarrow Fe^{2+}(aq)$	+0.77
$I_2(s) + 2e^- \rightarrow 2I^-(aq)$	+0.54
$O_2(g) + 2H_2O(l) + 4e^- \rightarrow 4OH^-(aq)$	+0.40
$Cu^{2+}(aq) + 2e^- \rightarrow Cu(s)$	+0.34
$SO_4^{2-}(aq) + 4H^+(aq) + 2e^- \rightarrow H_2SO_3(aq) + H_2O(l)$	+0.20
$Sn^{4+}(aq) + 2e^- \rightarrow Sn^{2+}(aq)$	+0.15
$^1/_8S_8(s) + 2H^+(aq) + 2e^- \rightarrow H_2S(aq)$	+0.14
$AgBr(s) + e^- \rightarrow Ag(s) + Br^-(aq)$	+0.07
$2H^+(aq) + 2e^- \rightarrow H_2(g)$	0.00
$Fe^{3+}(aq) + 3e^- \rightarrow Fe(s)$	−0.04
$Pb^{2+}(aq) + 2e^- \rightarrow Pb(s)$	−0.13
$Sn^{2+}(aq) + 2e^- \rightarrow Sn(s)$	−0.14
$AgI(s) + e^- \rightarrow Ag(s) + I^-(aq)$	−0.15
$Ni^{2+}(aq) + 2e^- \rightarrow Ni(s)$	−0.23
$Co^{2+}(aq) + 2e^- \rightarrow Co(s)$	−0.28
$PbSO_4(s) + 2e^- \rightarrow Pb(s) + SO_4^{2-}(aq)$	−0.36
$Cd^{2+}(aq) + 2e^- \rightarrow Cd(s)$	−0.40
$Fe^{2+}(aq) + 2e^- \rightarrow Fe(s)$	−0.41
$Cr^{3+}(aq) + e^- \rightarrow Cr^{2+}(aq)$	−0.41
$2H_2O(l) + 2e^- \rightarrow 2OH^-(aq)\ (1 \times 10^{-7}\ \frac{mol}{L}) + H_2(g)$	−0.42
$Cr^{3+}(aq) + 3e^- \rightarrow Cr(s)$	−0.74
$Zn^{2+}(aq) + 2e^- \rightarrow Zn(s)$	−0.76
$2H_2O(l) + 2e^- \rightarrow H_2(g) + 2OH^-(aq)$	−0.83
$SO_4^{2-}(aq) + H_2O(l) + 2e^- \rightarrow SO_3^{2-}(aq) + 2OH^-(aq)$	−0.92
$Al^{3+}(aq) + 3e^- \rightarrow Al(s)$	−1.66
$Mg^{2+}(aq) + 2e^- \rightarrow Mg(s)$	−2.38
$Na^+(aq) + e^- \rightarrow Na(s)$	−2.71
$Ca^{2+}(aq) + 2e^- \rightarrow Ca(s)$	−2.76
$Ba^{2+}(aq) + 2e^- \rightarrow Ba(s)$	−2.90
$K^+(aq) + e^- \rightarrow K(s)$	−2.92
$Li^+(aq) + e^- \rightarrow Li(s)$	−3.05

Note: Unless otherwise indicated
— all ions in this table are in aqueous solution
— all concentrations are 1.0 mol/L and all gases are at 101 kPa pressure
— $E°$ values have been measured at 298 K (25°C)

SOLUBILITY OF SOME IONIC COMPOUNDS IN WATER AT 298 K (25°C)

ION	Group IA: alkali metal ions	Group IA: H^+ (H_3O^+)	NH_4^+	NO_3^-	CH_3COO^-	Cl^- Br^- I^-	SO_4^{2-}	S^{2-}	OH^-	PO_4^{3-} SO_3^{2-} CO_3^{2-}
SOLUBILITY OF >0.1 mol/L (VERY SOLUBLE)	All	All	All	All	Most	Most	Most	Group IA Group IIA NH_4^+	Group IA NH_4^+ Sr^{2+} Ba^{2+} Tl^+	Group IA NH_4^+
SOLUBILITY OF <0.1 mol/L (SLIGHTLY SOLUBLE)	None	None	None	None	Ag^+	Ag^+ Pb^{2+} Hg_2^{2+} Cu^+ Tl^+	Ca^{2+} Sr^{2+} Ba^{2+} Ra^{2+} Ag^+ Pb^{2+}	Most	Most	Most

ADVANCE NOTICE CONCERNING GRADE XII PROVINCIAL DIPLOMA EXAMINATION SUBJECTS

1. Students must write a Provincial diploma examination in Chemistry 30 in order to be recommended for high school credits.

   The Provincial diploma examination is to be written in addition to the final test in Chemistry 30 set by the Alberta Correspondence School.

2. The Provincial diploma examination will be administered by Alberta Education and will be held three times yearly—in the last weeks of January and June, and in early August.

3. The results of this examination will count 50 per cent toward the final mark for Chemistry 30, with the mark from the Alberta Correspondence School test and course work making up the remaining 50 per cent.

4. The pass mark on both the Provincial diploma examination and the Correspondence School final test is 50 per cent.

   Students who fail their Provincial diploma examination can either request that their examination be remarked, or they can rewrite the examination at a later date.

   Students who fail the final test set by the Correspondence School can write an appeal test. Such appeal tests must be written within 60 days and before the student's registration expires.

Classroom Students

Classroom students are those who are enrolled in at least one subject in a high school which follows the Alberta curriculum.

Classroom students will be expected to sit for both their Provincial diploma examination and their Correspondence School final test at the high school in which they are enrolled.

The final test will be mailed to principals for all eligible students when courses are completed or during the summer months at the end of August.

Non-classroom Students

Non-classroom students are those who are not enrolled in a normal high school in Alberta or the Northwest Territories.

Such students are eligible to write their Correspondence School final test any time after the submission of at least eighteen satisfactory lessons in Chemistry 30. This test may be written at any office of the Correspondence School, or under the supervision of an acceptable test supervisor.

It is recommended that this final test be written before the student sits for the Provincial diploma examination.

Non-classroom students are expected to write their Provincial diploma examination at the nearest convenient high school, during one of the three yearly sittings. Information concerning the procedures for applying to write the Provincial diploma examination will be provided to non-classroom students at an appropriate time in their courses.

Procedures for out-of-province students will also be provided at an appropriate time.

No high school credits will be granted for Chemistry 30 until both the Provincial diploma examination mark and the Correspondence School's final mark are reported to Student Records and Computing Services Branch.

How Your Work in Chemistry 30 Will Be Evaluated

Your final mark in Chemistry 30 as assigned by the Alberta Correspondence School will be determined on the following basis:

All Lesson Work	30%	(See page ix)
Final Test	70%	
Total	100%	

For the lesson portion to be considered in the calculation of your final mark, you will need to obtain at least 40% on the final test. Please be aware that lessons must be submitted before the final test is written. Course work received by the Alberta Correspondence School after the test is written will not count toward your final mark.

The Chemistry 30 Diploma Examination and the Alberta Correspondence School's final test in Chemistry 30 are Closed Book tests. On both tests, you will be given a Data Booklet which has the various constants and formulas that you may need. Non-programmable calculators in which the memory has been cleared are also allowed on both tests.

Provisions for Mature Students

For the purpose of the Diploma Examinations Program, a "mature student" is one who meets one of the following requirements:

a. a student with a valid Alberta high school diploma
b. a student 20 years old or older
c. a student 19 years old, provided that after having reached the age of 18 years, the student left school and remained out of school for at least eight consecutive months.

Mature students may write any diploma examination for 100% of the final mark without having taken formal instruction in the course.

If a mature student enrolls in a diploma examination course at an approved Alberta High School, the final course mark will be either a blended one or, if the school-awarded course mark is equal to or less than the diploma examination, the final mark will be the examination mark only.

Enclosed are copies of Examinations for Chemistry 30 along with the answers. It would be good if you did these on your own (in 2½ hours) before you write the Diploma Examination. Then mark your own paper and try to understand why you made various errors. On both the test as well as the diploma Examination, you may only use the Data Booklet.

GRADE 12 DIPLOMA EXAMINATION

Chemistry 30

June 1985

Alberta
EDUCATION

DUPLICATION OF THIS PAPER IN ANY MANNER OR ITS USE FOR PURPOSES OTHER THAN THOSE AUTHORIZED AND SCHEDULED BY ALBERTA EDUCATION IS STRICTLY PROHIBITED.

GRADE 12 DIPLOMA EXAMINATION
CHEMISTRY 30

DESCRIPTION

Time: 2½ hours

Total possible marks: 70

This is a **CLOSED-BOOK** examination consisting of two parts:

PART A: 56 multiple-choice questions each with a value of 1 mark.

PART B: Three written-response questions for a total of 14 marks.

A chemistry data booklet is provided for your reference. Approved calculators may be used.

GENERAL INSTRUCTIONS

Fill in the information on the answer sheet as directed by the examiner.

For multiple-choice questions, read each carefully and decide which of the choices BEST completes the statement or answers the question. Locate that question number on the answer sheet and fill in the space that corresponds to your choice. USE AN HB PENCIL ONLY.

Example **Answer Sheet**

This examination is for the subject area of

A	B	C	D
●	②	③	④

A. Chemistry
B. Biology
C. Physics
D. Mathematics

If you wish to change an answer, please erase your first mark completely.

For written-response questions, read each carefully, show all your calculations, and write your answer in the space provided in the examination booklet.

NOTE: The perforated pages at the back of this booklet may be torn out and used for your rough work.

DO NOT FOLD EITHER THE ANSWER SHEET OR THE EXAMINATION BOOKLET

The presiding examiner will collect the answer sheet and examination booklet for transmission to Alberta Education.

JUNE 1985

PART A

INSTRUCTIONS

There are 56 multiple-choice questions with a value of one mark each in this section of the examination. Use the separate answer sheet provided and follow the specific instructions given.

NOTE: The perforated pages at the back of this booklet may be torn out and used for your rough work.

WHEN YOU HAVE COMPLETED PART A, PROCEED DIRECTLY TO PART B

DO NOT TURN THE PAGE TO START THE EXAMINATION UNTIL TOLD TO DO SO BY THE PRESIDING EXAMINER.

1. The potential energy of a substance includes the

   A. momentum of its molecules
   B. energy of its chemical bonds
   C. vibrational energy of the nuclei
   D. rotating motion of its molecules

2. When ice at 0°C changes to water at 0°C there is an increase in

   A. kinetic energy only
   B. potential energy only
   C. both kinetic and potential energy
   D. kinetic energy but a decrease in potential energy

3. For the chemical reaction $H_{2(g)} + V_2O_{3(s)} \longrightarrow 2VO_{(s)} + H_2O_{(g)}$, the substance that has a standard enthalpy of formation equal to zero is

   A. $H_{2(g)}$
   B. $VO_{(s)}$
   C. $H_2O_{(g)}$
   D. $V_2O_{3(s)}$

4. A student burned carbon in excess oxygen and determined the heat of combustion to be -405.2 kJ/mol. The percentage error for this empirical value is

   A. 2.89%
   B. 2.97%
   C. 11.7%
   D. 26.7%

5. The energy change that would NOT be exothermic is the

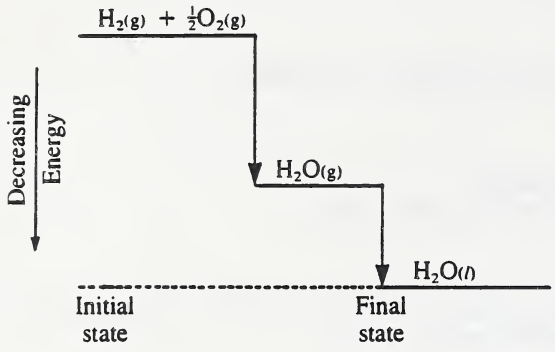
   A. freezing of water on a skating rink
   B. formation of snow from moisture in the air
   C. evaporation of water from the surface of a lake
   D. formation of rain droplets from water vapor in the air

6. If an exothermic reaction occurs in an insulated container, the temperature in the container will

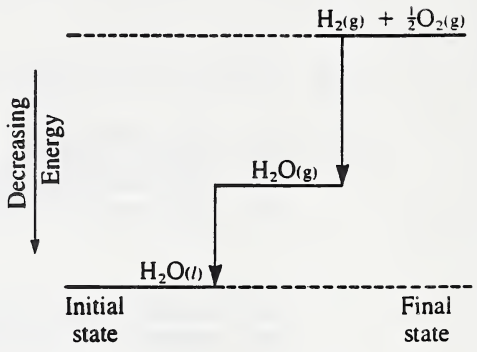
   A. decrease
   B. increase
   C. remain constant
   D. be impossible to measure

7. A student produces water in the laboratory by burning hydrogen gas in air. The diagram that illustrates the total change in energy is

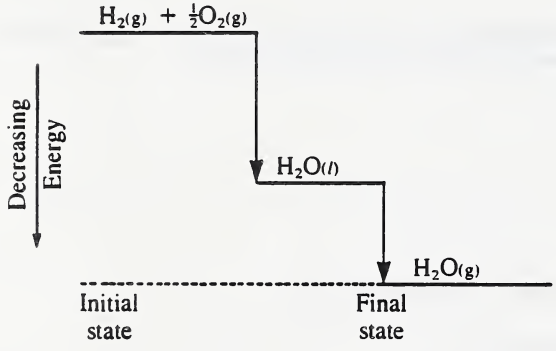
A.



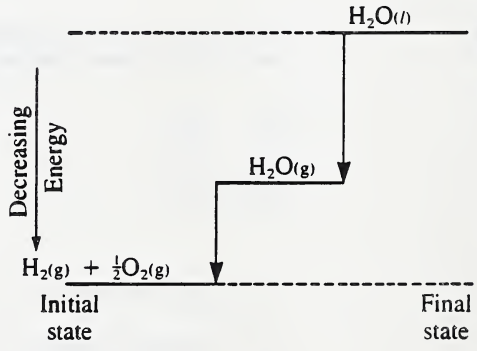
B.



C.



D.



8. The heat change associated with the burning of gasoline in a car is most likely to be

A. + 1000 kJ/mol
B. + 10 kJ/mol
C. − 1000 kJ/mol
D. − 1 000 000 kJ/mol

9. When steam at 100°C condenses, the energy released results mainly from the formation of

   A. ionic bonds
   B. covalent bonds
   C. intermolecular bonds
   D. bonds between nucleons

10. The heat of reaction for $AB + XY \longrightarrow ABXY$ can be calculated using the formula

    A. heat content of (AB + XY) + heat content of ABXY
    B. heat content of (AB + XY) − heat content of ABXY
    C. heat content of ABXY − heat content of (AB + XY)
    D. heat content of AB + heat content of XY

11. The total heat released by the combustion of propane gas is primarily dependent upon the

    A. temperature change
    B. atmospheric pressure
    C. moles of reactants involved
    D. method of measuring the heat released

12. The burning of 12.0 g of urea, $CO(NH_2)_2$, raises the temperature of 1.00 L of water by 30.0°C. The heat released by the combustion of urea is

    A. 1510 kJ/mol
    B. 629 kJ/mol
    C. 126 kJ/mol
    D. 25.1 kJ/mol

Use the following information to answer question 13.

> 7.08 kJ of heat are required to raise the temperature of a calorimeter and its contents 1.0°C. When 0.90 g of ethane is ignited in a calorimeter, the temperature of the calorimeter and its contents rises 9.7°C.

13. The heat required for the combustion of ethane is

    A. 6.2×10^1 kJ/mol
    B. 1.4×10^3 kJ/mol
    C. 2.1×10^3 kJ/mol
    D. 2.3×10^3 kJ/mol

14. ΔH for the reaction $2KClO_{3(s)} \longrightarrow 2KCl_{(s)} + 3O_{2(g)}$ is

A. -44.7 kJ
B. -89.4 kJ
C. -871.8 kJ
D. -1654 kJ

Use the following information to answer question 15.

$$H_{2(g)} + L_{2(g)} + 62.85 \text{ kJ} \longrightarrow 2HL_{(g)}$$

$$H_{2(g)} + L_{2(g)} \longrightarrow 2HL_{(l)} + 29.33 \text{ kJ}$$

15. In the reaction $HL_{(l)} \longrightarrow HL_{(g)}$,

A. 92.18 kJ of heat energy are released per mole of $HL_{(g)}$
B. 46.09 kJ of heat energy are released per mole of $HL_{(g)}$
C. 92.18 kJ of heat energy are absorbed per mole of $HL_{(g)}$
D. 46.09 kJ of heat energy are absorbed per mole of $HL_{(g)}$

16. When 2.70 g of aluminum burns, 83.5 kJ of heat are released. This is consistent with

A. $4Al_{(s)} + 3O_{2(g)} \longrightarrow 2Al_2O_{3(s)} + 1670$ kJ

B. $4Al_{(s)} + 3O_{2(g)} \longrightarrow 2Al_2O_{3(s)} + 3340$ kJ

C. $4Al_{(s)} + 3O_{2(g)} + 3340 \text{ kJ} \longrightarrow 2Al_2O_{3(s)}$

D. $4Al_{(s)} + 3O_{2(g)} + 1670 \text{ kJ} \longrightarrow 2Al_2O_{3(s)}$

17. Consider the equation $6CH_3COOH_{(l)} + 11O_{2(g)} \longrightarrow 10CO_{2(g)} + 2CO_{(g)} + 12H_2O_{(l)}$. If 12.0 g of $CH_3COOH_{(l)}$ react, the heat released is

A. 155 kJ
B. 350 kJ
C. 778 kJ
D. 4660 kJ

Use the following information to answer question 18.

Assume that the amount of heat produced by the fusion of 2 mol of H atoms is 1.7×10^9 kJ.

18. The number of moles of $H_{2(g)}$ that must be burned to produce liquid water and this same amount of heat is

A. 6.0×10^{10} mol
B. 5.9×10^{6} mol
C. 1.7×10^{-7} mol
D. 2.0×10^{-9} mol

---

19. The hydrogen oxalate ion, $HOOCCOO^-$, is formed when oxalic acid is added to water. The resulting solution

A. tastes bitter
B. neutralizes acids
C. has a slippery feel
D. changes blue litmus to red

20. A neutralization reaction is represented by

A. $Ba^{2+}_{(aq)} + CrO_4^{2-}{}_{(aq)} \longrightarrow BaCrO_{4(s)}$

B. $2NO_3^-{}_{(aq)} + 4H^+_{(aq)} \longrightarrow 2H_2O_{(l)} + 2NO_{2(g)}$

C. $NaOH_{(aq)} + HClO_{4(aq)} \longrightarrow NaClO_{4(aq)} + H_2O_{(l)}$

D. $2CrO_4^{2-}{}_{(aq)} + 2H^+_{(aq)} \longrightarrow Cr_2O_7^{2-}{}_{(aq)} + H_2O_{(l)}$

21. In an acidic solution, the concentration of the hydronium ions compared to the hydroxide ions is

A. 1.0×10^{-7} mol/L
B. the same
C. smaller
D. larger

22. Which of the following statements does NOT agree with the Brønsted-Lowry definition of acids and bases?

A. Water may act as an acid or as a base.
B. Acid-base reactions may involve the hydronium ion.
C. Acid-base reactions involve a transfer of hydrogen ions.
D. Acid-base reactions involve a transfer of hydroxide ions.

23. Consider the equation $H_2PO_4^-(aq) + CH_3COO^-(aq) \rightleftharpoons HPO_4^{2-}(aq) + CH_3COOH(aq)$. The correct statement is:

A. $HPO_4^{2-}(aq)$ reacts as a base.
B. $CH_3COOH(aq)$ reacts as a base.
C. $CH_3COO^-(aq)$ reacts as an acid.
D. $H_2PO_4^-(aq)$ reacts as both an acid and a base.

24. When equal volumes of 0.10 mol/L $H_2PO_4^-(aq)$ and 0.10 mol/L $HSO_4^-(aq)$ are mixed, the base is

A. $H_3O^+(aq)$
B. $HSO_4^-(aq)$
C. $H_2PO_4^-(aq)$
D. $H_3PO_4(aq)$

25. When used to describe a property of acids, the term "strong" means that the acid

A. is caustic
B. has a high pH
C. is concentrated
D. dissociates completely

26. The pH of a 0.001 mol/L LiOH solution is

A. 3
B. 7
C. 10
D. 11

27. As a solution becomes more basic, the

A. $[H_3O^+(aq)]$ decreases and the pH increases
B. $[H_3O^+(aq)]$ decreases and the pH decreases
C. $[H_3O^+(aq)]$ increases and the pH increases
D. $[H_3O^+(aq)]$ increases and the pH decreases

28. If the pH of a solution is 8.0, the

A. $[H_3O^+(aq)]$ is 8.0 times as great as the $[OH^-(aq)]$
B. $[OH^-(aq)]$ is greater than 1.0×10^{-7} mol/L
C. $[OH^-(aq)]$ is 1.0×10^{-8} mol/L
D. $[H_3O^+(aq)]$ is 8.0 mol/L

29. When the $[OH^{-}_{(aq)}]$ of a solution is changed from 10^{-1} mol/L to 10^{-3} mol/L, the indicator

A. methyl orange will remain red
B. phenolphthalein will remain colorless
C. orange IV will change from red to yellow
D. indigo carmine will change from yellow to blue

Use the following information to answer question 30.

Various indicators are added one at a time to a solution that has been divided equally among five test tubes.

TEST TUBE	INDICATOR ADDED	COLOR OF SOLUTION
1	orange IV	yellow
2	methyl orange	yellow
3	bromocresol green	blue
4	methyl red	orange
5	bromothymol blue	yellow

30. The pH range of the solution is

A. 3.0 to 4.0
B. 4.0 to 5.0
C. 5.0 to 6.0
D. 6.0 to 7.0

---

31. If the $[OH^{-}_{(aq)}]$ of a solution is 1.43×10^{-4} mol/L, the $[H_3O^{+}_{(aq)}]$ is

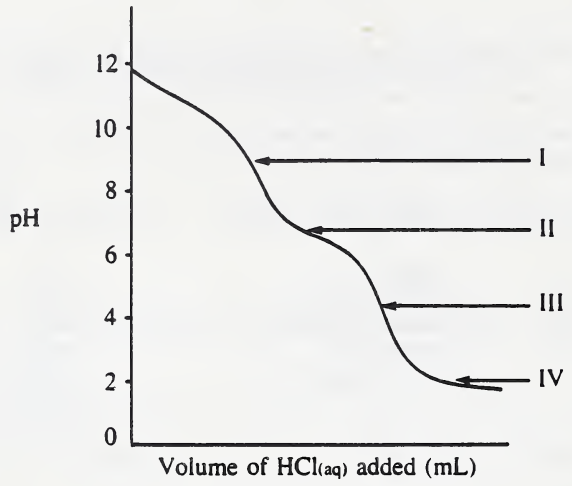
A. 1.43×10^{-4} mol/L
B. 2.43×10^{-10} mol/L
C. 6.99×10^{-11} mol/L
D. 1.00×10^{-14} mol/L

32. At a given temperature, 20% of 0.40 mol/L $CH_3COOH_{(aq)}$ dissociates. The resulting $[H_3O^{+}_{(aq)}]$ is

A. 4.0×10^{-2} mol/L
B. 8.0×10^{-2} mol/L
C. 4.0×10^{-1} mol/L
D. 8.0×10^{-1} mol/L

Use the following information to answer questions 33 and 34.

Hydrochloric acid is continuously added to a sodium carbonate solution that contains the indicators phenolphthalein and bromocresol green. A pH meter was used to obtain the data for the titration curve shown below.



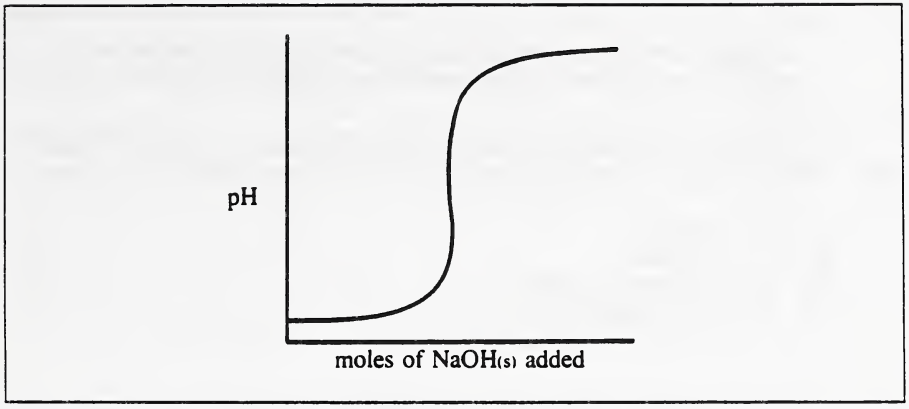
33. The Brønsted-Lowry base reacting at region II would be

A. $CO_3^{2-}{}_{(aq)}$
B. $HCO_3^-{}_{(aq)}$
C. $H_2CO_{3(aq)}$
D. $Cl^-{}_{(aq)}$

34. Bromocresol green indicator would indicate an endpoint at

A. I
B. II
C. III
D. IV

Use the following information to answer question 35.



35. As the titration shown by the graph progresses, the

A. $[OH^-_{(aq)}]$ decreases
B. $[H_3O^+_{(aq)}]$ increases
C. $[H_3O^+_{(aq)}]$ decreases
D. $[OH^-_{(aq)}]$ remains constant

---

36. The volume of 0.50 mol/L $HClO_{4(aq)}$ required to neutralize 200.0 mL of 0.60 mol/L $Ba(OH)_{2(aq)}$ is

A. 120 mL
B. 200 mL
C. 240 mL
D. 480 mL

37. A 40.0 mL solution of 5.0×10^{-4} mol/L HCl is added to 100.0 mL of 1.3×10^{-4} mol/L NaOH. The resulting pH is

A. 7.0
B. 4.3
C. 3.8
D. 3.3

38. An example of an oxidation half-reaction is

A. $Na_{(s)} \longrightarrow Na^+_{(aq)} + e^-$

B. $Cl_{2(g)} + 2e^- \longrightarrow 2Cl^-_{(aq)}$

C. $Fe^{3+}_{(aq)} + e^- \longrightarrow Fe^{2+}_{(aq)}$

D. $MnO^-_{4(aq)} + 8H^+_{(aq)} + 5e^- \longrightarrow Mn^{2+}_{(aq)} + 4H_2O_{(l)}$

Use the following information to answer question 39.

A strip of metal X is placed in a test tube containing a green solution of Z^+. After a short time, the green color disappears and a solid forms on the bottom of the tube.

39. Which statement is the best interpretation of the observations?

A. X is reduced.
B. Z^+ is reduced.
C. Z^+ is the reducing agent.
D. X is the oxidizing agent.

---

40. In the reaction $X + T^{3+} \longrightarrow X^+ + T^{2+}$, the reducing agent is

A. X
B. X^+
C. T^{3+}
D. T^{2+}

41. The balanced net ionic equation for the reaction between $Pb_{(s)}$ and $Ag^+_{(aq)}$ is

A. $Pb_{(s)} + 2Ag^+_{(aq)} + 2e^- \longrightarrow 2PbAg_{(s)}$
B. $Pb_{(s)} + Ag^+_{(aq)} \longrightarrow Pb^{2+}_{(aq)} + Ag_{(s)}$
C. $Pb_{(s)} + 2Ag^+_{(aq)} \longrightarrow Pb^{2+}_{(aq)} + 2Ag_{(s)}$
D. $Pb_{(s)} + 2Ag^+_{(aq)} + 2e^- \longrightarrow Pb^{2+}_{(aq)} + 2Ag_{(s)} + 2e^-$

42. The expression that illustrates an electron loss is

A. $H \longrightarrow H^+$
B. $Cl \longrightarrow Cl^-$
C. $Fe^{3+} \longrightarrow Fe^{2+}$
D. $ClO_3^- \longrightarrow ClO_2^-$

43. Consider the equation $3Hg_{(g)} + 2AuCl_{4(aq)}^- \longrightarrow 3Hg^{2+}_{(aq)} + 2Au_{(s)} + 8Cl^-_{(aq)}$. The CHANGE in the oxidation number of Au in this reaction is

A. 0
B. 1
C. 3
D. 6

Use the following information to answer question 44.

The unbalanced equation for the reaction of Br^- with MnO_4^- is
$Br^-_{(aq)} + MnO^-_{4(aq)} + H^+_{(aq)} \longrightarrow Br_{2(l)} + Mn^{2+}_{(aq)} + H_2O_{(l)}$.

44. When the equation is balanced using the smallest possible whole numbers, the coefficient of $MnO^-_{4(aq)}$ is

A. 1
B. 2
C. 4
D. 5

---

45. The number of moles of electrons needed to convert 4.0 g of $Ca^{2+}_{(aq)}$ to calcium metal is

A. 0.10 mol
B. 0.20 mol
C. 1.0 mol
D. 2.0 mol

46. When 8.1 g of $Al_{(s)}$ react with excess $HCl_{(aq)}$, the mass of $H_{2(g)}$ formed is

A. 0.15 g
B. 0.30 g
C. 0.45 g
D. 0.91 g

47. The half-cell reaction that is used as a standard for the comparison of reduction potentials is

A. $Li^+_{(aq)} + e^- \longrightarrow Li_{(s)}$

B. $F_{2(g)} + 2e^- \longrightarrow 2F^-_{(aq)}$

C. $2H^+_{(aq)} + 2e^- \longrightarrow H_{2(g)}$

D. $O_{2(g)} + 4H^+_{(aq)} + 4e^- \longrightarrow 2H_2O_{(l)}$

48. If $Br_{2(l)} + 2e^- \longrightarrow 2Br^-_{(aq)}$ is assigned a potential of 0.00 V, then the potential for $K^+_{(aq)} + e^- \longrightarrow K_{(s)}$ is

A. −3.99 V
B. −2.92 V
C. −1.85 V
D. −1.07 V

49. $Ag^{+}_{(aq)}$ can be reduced by

A. $Au_{(s)}$

B. $F^{-}_{(aq)}$

C. $Cl_{2(g)}$

D. $Fe^{2+}_{(aq)}$

Use the following information to answer question 50.

Four elements, Z, T, X, and R, form diatomic molecules and negative ions. The following observations are made:

$$Z_2 + 2X^- \longrightarrow 2Z^- + X_2$$
$$T_2 + 2R^- \longrightarrow \text{no reaction}$$
$$X_2 + 2R^- \longrightarrow 2X^- + R_2$$

50. When the elements are arranged in order from most reactive to least reactive, the list is

A. Z_2, X_2, R_2, T_2
B. T_2, R_2, X_2, Z_2
C. T_2, R_2, Z_2, X_2
D. T_2, X_2, R_2, Z_2

---

51. The standard potential of a zinc-acidified dichromate electrochemical cell is

A. +0.35 V
B. +0.57 V
C. +1.17 V
D. +2.09 V

52. A zinc anode and an unknown cathode are connected to form a cell with a net potential of 1.59 V. The electrode potential for the reduction half-reaction is

A. −1.59 V
B. −0.76 V
C. +0.83 V
D. +2.35 V

53. Which of the following reactions would occur spontaneously?

A. $Fe_{(s)} + 2Cl^-_{(aq)} \longrightarrow Fe^{2+}_{(aq)} + Cl_{2(g)}$

B. $Cu^{2+}_{(aq)} + 2Ag_{(s)} \longrightarrow Cu_{(s)} + 2Ag^+_{(aq)}$

C. $Cu^{2+}_{(aq)} + Sn^{2+}_{(aq)} \longrightarrow Cu_{(s)} + Sn^{4+}_{(aq)}$

D. $MnO^-_{4(aq)} + 8H^+_{(aq)} + Pb^{2+}_{(aq)} \longrightarrow Pb_{(s)} + Mn^{2+}_{(aq)} + 4H_2O_{(l)}$

54. If, during the electrolysis of molten aluminum oxide, $Al_2O_{3(l)}$, a current of 2.0 A flows for 50 min, the number of moles of $Al_{(s)}$ that will be deposited is

A. 6.2×10^{-2} mol
B. 2.1×10^{-2} mol
C. 1.0×10^{-3} mol
D. 3.5×10^{-4} mol

55. A process that involves a change from chemical energy into electrical energy is the

A. discharging of a lead storage battery
B. recharging of an Ni-Cd cell
C. electroplating of silver
D. electrolysis of water

56. During the electroplating of silver spoons, silver is deposited by

A. oxidizing silver ions at the cathode
B. reducing silver ions at the cathode
C. oxidizing silver ions at the anode
D. reducing silver ions at the anode

YOU HAVE NOW COMPLETED THE MULTIPLE-CHOICE SECTION OF THE EXAMINATION. PLEASE PROCEED TO THE NEXT PAGE AND ANSWER THE WRITTEN-RESPONSE QUESTIONS IN PART B.

PART B

INSTRUCTIONS

Please write your answers in the examination booklet as neatly as possible.

Marks will be awarded for pertinent explanations, calculations, formulas, and answers. Answers must be given to the appropriate number of significant digits.

NOTE: The perforated pages at the back of this booklet may be torn out and used for your rough work.

TOTAL MARKS: 14

START PART B IMMEDIATELY

(5 marks) 1. A student is required to determine the heat of reaction for $Ca_{(s)} + \frac{1}{2}O_{2(g)} \longrightarrow CaO_{(s)}$ using the following reactions and the data collected.

Reaction I $Ca_{(s)} + 2HCl_{(aq)} \longrightarrow CaCl_{2(aq)} + H_{2(g)}$ $\Delta H = ?$

Reaction II $CaO_{(s)} + 2HCl_{(aq)} \longrightarrow CaCl_{2(aq)} + H_2O_{(l)}$ $\Delta H = ?$

Reaction III $H_{2(g)} + \frac{1}{2}O_{2(g)} \longrightarrow H_2O_{(l)}$ $\Delta H = -285.9$ kJ

Reaction	Mass	Volume 1.0 mol/L $HCl_{(aq)}$	Initial Temperature	Final Temperature
I	0.50 g $Ca_{(s)}$	1.00×10^2 mL	22.3°C	35.9°C
II	1.50 g $CaO_{(s)}$	1.00×10^2 mL	22.0°C	29.1°C

Assume specific heat and density of $HCl_{(aq)}$ are the same values as for water.

a. Determine the ΔH value per mole of $Ca_{(s)}$ in Reaction I.

b. Determine the ΔH value per mole of $CaO_{(s)}$ in Reaction II.

c. Using reactions I, II, and III, determine the ΔH value for the combustion of $Ca_{(s)}$.

(5 marks) 2. a. Write two net ionic equations that correctly illustrate the role of the dihydrogen phosphate ion as an acid and as a base, using nitric acid and the hydrogen carbonate ion. List the conjugate acid-base pairs for each reaction.

Equations:

Equation 1 (using nitric acid)

_____

Equation 2 (using the hydrogen carbonate ion)

_____

Conjugate acid-base pairs:

Equation 1 _____acid_____ – _____base_____

_____ – _____

_____ – _____

Equation 2 _____acid_____ – _____base_____

_____ – _____

_____ – _____

b. Predict whether reactants or products are favored for each equation in part a.

equation 1 _____ favored

equation 2 _____ favored

Use the following information to answer question 3.

You are given unlabelled strips of magnesium, tin, and zinc, as well as the following 1.0 mol/L solutions:

$Ca(NO_3)_{2(aq)}$	$Cu(NO_3)_{2(aq)}$
$Co(NO_3)_{2(aq)}$	$Fe(NO_3)_{2(aq)}$
$Al(NO_3)_{3(aq)}$	$Pb(NO_3)_{2(aq)}$

(4 marks) 3. Describe an experimental procedure using oxidation-reduction reactions that would enable you to identify each metal. Indicate the chemicals that you would use and explain how the results would enable you to identify the metals.

YOU HAVE NOW COMPLETED THE EXAMINATION. IF YOU HAVE TIME, YOU MAY WISH TO GO BACK AND CHECK YOUR ANSWERS.

1. B refer to Chapters 5 and 11 of text; Lesson 6
A, C, D are examples of kinetic energy

2. B a phase change does not involve a change in kinetic energy

3. A refer to note on page 3 of data booklet (standard heats of formation)

4. B $$\% \text{ error} = \frac{\text{standard value - experimental value}}{\text{standard value}} \times 100\%$$

$$= \frac{393.5 \text{ kJ/mol} - (-405.2 \text{ kJ/mol})}{-393.5 \text{ kJ/mol}} \times 100\%$$

$$= 2.97\%$$

5. C answers A, B, D involve a phase change releasing energy, evaporation requires energy (endothermic)

6. B exothermic reactions release heat thus increasing the temperature in the container.

7. A initial states are $H_{2(g)}$ and $\frac{1}{2}\ O_{2(g)}$ producing $H_2O_{(g)}$ then finally $H_2O_{(l)}$

8. C Exothermic reactions have a ΔH which is negative thus A and B are eliminated as answers. If you calculate the heat released using the standard heats of formation the optimum value for octane is about -5000 kJ/mol. Thus -1000 kJ/mol is the most reasonable answer.

9. C intermolecular bond strengths determine the melting and boiling points of substances

10. C ΔH = (heat of products) - (heat of reactants)

11. C more moles of reactants will release more heat

12. B heat released $= (1000 \text{ g})\ (30^\circ\text{C})\ (4.19 \text{ J/g}^\circ\text{C})$

$$= 125\ 700 \text{ J}$$

$$= 125.7 \text{ kJ}$$

$$\text{number of moles of urea} = \frac{12.0 \text{ g}}{60.07 \text{ g/mol}} = 0.200 \text{ mol}$$

$$\text{molar heat of combustion} = \frac{125.7 \text{ kJ}}{0.200 \text{ mol}} = 629 \text{ kJ/mol}$$

13. D number of moles of ethane (C_2H_6) is:

$$\frac{0.90\ g}{30.08\ g/mol} = 0.0299\ mol$$

heat absorbed = (7.08 kJ/°C) (9.7°C)
= 68.676 kJ

molar heat of combustion of ethane is

$$\frac{68.676\ kJ}{0.0299\ mol} = 2297\ kJ/mol$$
$$= 2.3 \times 10^3\ kJ/mol$$

correct to 2 significant figures.

14. B ΔH = (heat of products) - (heat of reactants)
= [2(-435.9) + 3(Ø)] - [2(-391.2)]
= -89.4 kJ

15. D $2HL_{(l)} + 29.33\ kJ \longrightarrow H_{2(g)} + L_{2(g)}$

$H_{2(l)} + L_{2(g)} + 62.85\ kJ \longrightarrow 2HL_{(g)}$

$2HL_{(l)} + 92.18\ kJ \longrightarrow 2HL_{(g)}$

$\therefore$ 1 mol $HL_{(l)}$ absorbs $\frac{92.18\ kJ}{2} = 46.09\ kJ$ of heat to produce 1 mol of $HL_{(g)}$.

16. B 27 g of Al = $\frac{2.7\ g}{26.98\ g/mol} = 0.10\ mol$

molar heat of reaction is $\frac{83.5\ kJ}{0.10\ mol} = 835\ kJ/mol$

4 mol of Al would release (4 mol) (835 kJ/mol)

= 3340 kJ

17. A ΔH = [10(-393.5) + 2(-110.5) + 12(-285.9)] -
[6(-487.0) + 11(Ø)]

= -7586.8 + 2922

= -4664.8 kJ for 6 mol of CH_3COOH

$\therefore$heat released = $\frac{4664.8\ kJ}{6\ mol}$ (0.199 mol)

= 155 kJ

18. B $H_{2(g)} + \frac{1}{2}O_{2(g)} \longrightarrow H_2O_{(l)} + 285.9\ kJ$

$\therefore \frac{1.7 \times 10^9\ kJ}{285.9\ kJ/mol} = 5.9 \times 10^6\ mol$

of $H_{2(g)}$ must be burned to produce 1.7×10^9 kJ of heat.

19. D acids change blue litmus red

20. C acid-base neutralization produces salt and water

21. D $[H_3O^+]$ must be greater than $[OH^-]$ to have an acidic solution.

22. D refer to Lesson 13 p. 1

23. A HPO_4^{2-} accepts a proton from CH_3COOH to form $H_2PO_4^-$.

24. C $HSO_{4(aq)}^- + H_2PO_{4(aq)}^- \rightleftharpoons SO_{4(aq)}^{2-} + H_3PO_{4(aq)}$

ACID BASE

25. D this is the definition of strong acids

26. D $[OH^-] = 10^{-3}$ mol/L

$[H^+] = \frac{10^{-14}}{10^{-3}} = 10^{-11}$ mol/L

$pH = -\log [H^+] = 11$

27. A more basic means $[OH^-_{(aq)}]$ increases while $[H_3O^+_{(aq)}]$ decreases and pH increases.

28. B $pH = -\log [H_3O^+_{(aq)}]$

$[H_3O^+_{(aq)}] = \text{antilog}\ [-pH]$

$[H_3O^+_{(aq)}] = 10^{-8}$ mol/L

$[OH^-_{(aq)}] = \frac{10^{-14}}{10^{-8}} = 10^{-6}$ mol/L

10^{-6} is greater than 10^{-7}

29. D $[H_3O^+_{(aq)}]$ changes from 10^{-13} mol/L to 10^{-11} mol/L

pH changes from 13 to 11

at pH = 13 indigo carmine is yellow
at pH = 11.4 indigo carmine is blue
(see data booklet)

30. C see data booklet

31. C $[H_3O^+_{(aq)}] = \frac{10^{-14}}{1.43 \times 10^{-4}} = 6.99 \times 10^{-11}$ mol/L

32. B $[H_3O^+_{(aq)}] = (0.40 \text{ mol/L } (0.2)$
$= 0.08$ mol/L
$= 8 \times 10^{-2}$ mol/L

33. B $H^+_{(aq)} + Cl^-_{(aq)} + 2Na^+_{(aq)} + CO^{2-}_{3(aq)}$

$\longrightarrow Cl^-_{(aq)} + 2Na^+_{(aq)} + HCO^-_{3(aq)}$

at level II the products have been formed and as more acid is added the reaction is:

$H^+_{(aq)} + 2Cl^-_{(aq)} + 2Na^+_{(aq)} + HCO^-_{3(aq)} \longrightarrow$

$2Cl^-_{(aq)} + 2Na^+_{(aq)} + H_2CO_{3(aq)}$

$\therefore$ the $HCO^-_{3(aq)}$ accepts the proton and is the Brønsted-Lowry base.

34. C range of Bromocresol green is 3.8 to 5.4

35. C adding $OH^-_{(aq)}$ decreases the $[H_3O^+_{(aq)}]$

36. D number of moles of $Ba(OH)_2$

(0.60 mol/L)(0.2000 L)

= 0.12 mol

the number of moles of $OH^-_{(aq)}$ from the equation.

$Ba(OH)_{2(aq)} \longrightarrow Ba^{2+}_{(aq)} + 2OH^-$

is 2 (0.12 mol) = 0.24 mol

$\therefore$ 0.24 mol of $HClO_4$ are required

Volume = $\frac{0.24 \text{ mol}}{0.50 \text{ mol/L}}$ = 0.48 L = 480 mL

37. B number of moles of $H^+_{(aq)}$ = (0.04 L) (5×10^{-4} mol/L)
$= 2 \times 10^{-5}$ mol

number of moles of $OH^-_{(aq)}$ = (0.1 L)(1.3×10^{-4} mol/L)
$= 1.3 \times 10^{-5}$ mol

excess $H^+ = 2 \times 10^{-5}$ mol $- 1.3 \times 10^{-5}$ mol
$= 7 \times 10^{-6}$ mol

$$\text{concentration} = \frac{7 \times 10^{-6} \text{ mol}}{0.140 \text{ L}} = 5 \times 10^{-5} \text{ mol/L}$$

$$pH = -\log [H^+_{(aq)}]$$

$$pH = 4.3$$

38. A oxidation is the loss of electrons (Lesson 15)

39. B One half-reaction must be $Z^+ + e^- \longrightarrow Z$ since Z^+ gains electrons Z^+ is reduced.

40. A reducing agent supplies the e^-

41. C read section 15-11 in text page 336

42. A H atom loses an e^- to form H^+ ion

43. C In $AuCl_4^-$ the oxidation numbers are

Cl = 1-
Au = 3+

In $Au_{(s)}$ the oxidation number is Ø thus the change is from 3+ to Ø.

44. B $2(MnO_4^-{}_{(aq)} + 8H^+_{(aq)} + 5e^- \longrightarrow Mn^{2+}_{(aq)} + 4H_2O_{(l)})$

$5(2Br^-_{(aq)} \longrightarrow Br_{2(l)} + 2e^-)$

$10Br^-_{(aq)} + 2MnO_4^-{}_{(aq)} + 16H^+_{(aq)} \longrightarrow 5Br_{2(l)} + 2Mn^{2+}_{(aq)} + 8H_2O_{(l)}$

45. B 4.0 g of $Ca^{2+}_{(aq)} = \frac{4.0 \text{ g}}{40.08 \text{ g/mol}} = 0.0998$ mol

1 mol Ca^{2+} requires 2 mol e^-

$\therefore$ number of moles of $e^- = 2(0.0998 \text{ mol})$
$= 0.20$ mol

46. D $2Al_{(s)} + 6H^+_{(aq)} + 6Cl^-_{(aq)} \longrightarrow 2AlCl_{3(s)} + 3H_{2(g)}$

$8.1\ g\ Al_{(s)} = \frac{8.1\ g}{26.98\ g/mol} = 0.30\ mol$

$\therefore (0.30\ mol)\ (\frac{3}{2}) = 0.45\ mol\ of\ H_{2(g)}$ is produced.

$0.45\ mol\ H_{2(g)} = (0.45\ mol)\ (2.02\ g/mol)$

$= 0.91\ g$

47. C In the table of standard electrode potentials this reaction is assigned the value Ø.

48. A $Br_{2(l)} + 2e^- \longrightarrow 2Br^-_{(aq)}$ $E^0 = 1.07\ V$

$K^+_{(aq)} + e^- \longrightarrow K_{(s)}$ $E^0 = -2.92\ V$

potential difference = 3.99 V

If the potential for $Br_{2(l)} + 2e^- \longrightarrow 2Br^-_{(aq)}$ is assigned Ø then the reaction $K^+_{(aq)} + e^- \longrightarrow K_{(s)}$ must be -3.99 V.

49. D Fe^{2+} is a stronger reducing agent than Ag^+

$Ag^+_{(aq)} + e^- \longrightarrow Ag_{(s)}$ $E^0 = 0.80\ V$

$Fe^{2+}_{(aq)} \longrightarrow Fe^{3+}_{(aq)} + e^-$ $E^0 = -0.77\ V$

$E^0 = 0.03\ V$

50. A Z_2 oxidizes X^- to X_2

X_2 oxidizes R^- to R_2

T_2 cannot oxidize R^-

refer to Lesson 16, page 8

51. D $3(Zn_{(s)} \longrightarrow Zn^{2+}_{(aq)} + 2e^-)$ $E^0 = +0.76\ V$

$Cr_2O_7^{2-}{}_{(aq)} + 14H^+_{(aq)} + 6e^- \longrightarrow 2Cr^{3+}_{(aq)} + 7H_2O_{(l)}$ $E^0 = +1.33\ V$

$E^0 = 2.09\ V$

$Cr_2O_7^{2-}{}_{(aq)} + 14H^+_{(aq)} + 3Zn_{(s)} \longrightarrow 3Zn^{2+}_{(aq)} + 2Cr^{3+}_{(aq)} + 7H_2O_{(l)}$

52. C At the anode $Zn \longrightarrow Zn^{2+} + 2e^- + 0.76\ V$

Net voltage is 1.59 V

$\therefore$ cathode reaction voltage is 0.83 V

$(1.59\ V - 0.76\ V) = 0.83\ V$

53. C Net voltages are

A : +0.04 V - 1.36 V = -1.32 V
B : +0.34 V - 0.80 V = -0.46 V
C : 0.34 V - 0.15 V = +0.19 V

D is two reduction half-reactions which should not be written and cannot be a oxidation-reduction reaction.

(See page 9 of Lesson 16)

54. B $Al^{3+} + 3e^- \longrightarrow Al_{(s)}$

The number of moles of e^-

$$= \frac{(2.0\ C/s)\ (50\ min)\ (60\ s/min)}{9.65 \times 10^4\ C/mol}$$

$= 0.062$ mol

The number of moles of Al produced is

$$\frac{0.062\ mol}{3} = 0.021\ mol$$

55. A read page 328 of text.

56. B reduction occurs at the cathode

read pp 313, 314 of text

SAMPLE ANSWERS TO THE WRITTEN-RESPONSE SECTION:
CHEMISTRY JUNE 1985

Note: The responses that follow represent ONE approach to each of the problems. During the diploma examination markingsession, provision is made for considering the various approaches students may have used.

1. a. heat gained by solution

$$1.00 \times 10^{2} \times \frac{4.19\ J}{g \cdot {}^{\circ}C} \times (35.9{}^{\circ}C - 22.3{}^{\circ}C) = 5.698 \times 10^{3}\ J$$
$$= 5.698\ kJ$$

moles of Ca(s):

$$0.50\ g \times \frac{1\ mol}{40.08\ g} = 0.0125\ mol$$

$$\Delta h : \frac{5.698\ kJ}{0.0125\ mol} = -460\ kJ/mol$$

b. heat gained by solution:

$$1.00 \times 10^{2}\ g \times \frac{4.19\ J}{g \cdot {}^{\circ}C} \times (29.1{}^{\circ}C - 22.0{}^{\circ}C) = 2.97 \times 10^{3}\ J$$
$$= 2.97\ kJ$$

moles of CaO(s):

$$1.50\ g \times \frac{1\ mol}{56.08\ g} = 0.0267\ mol$$

$$\Delta h: \frac{2.97\ kJ}{0.0267\ mol} = -1.1 \times 10^{2}\ kJ/mol$$

c.
$$Ca_{(s)} + HCl_{(aq)} \longrightarrow CaCl_{2(aq)} + H_{2(g)} \qquad \Delta h = -460\ kJ/mol$$
$$CaCl_{2(aq)} + H_2O_{(l)} \longrightarrow CaO_{(s)} + 2HCl_{(aq)} \qquad \Delta h = +110\ kJ/mol$$
$$H_{2(g)} + \tfrac{1}{2}O_{2(g)} \longrightarrow H_2O_{(l)} \qquad \Delta h = -285.9\ kJ/mol$$
$$Ca_{(s)} + \tfrac{1}{2}O_{2(g)} \longrightarrow CaO_{(s)} \qquad \Delta h = -636\ kJ/mol$$

2. a. equation 1. $H_2PO_4^-{}_{(aq)} + H_3O^+{}_{(aq)} \rightleftharpoons H_3PO_4{}_{(aq)} + H_2O_{(l)}$

equation 2. $H_2PO_4^-{}_{(aq)} + HCO_3^-{}_{(aq)} \rightleftharpoons HPO_4^{2-}{}_{(aq)} + H_2CO_3{}_{(aq)}$

equation 1. $H_3O^+(aq)$ - $H_2O(l)$

$H_3PO_4(aq)$ - $H_2PO_4(aq)$

equation 2. $H_2PO_4(aq)$ - HPO_4^{2-}

$H_2CO_3(aq)$ - HCO_3^-

b. equation 1. Products favored

equation 2. Reactants favored

3. Select solution containing metal ion between Mg^{2+} and Zn^{2+} on Standard Reduction Potential Table - $Al(NO_3)_{3\,(aq)}$. Select solution between Sn^{2+} and Zn^{2+} - $Co(NO_3)_{2\,(aq)}$ or $Fe(NO_3)_{2\,(aq)}$.

Place strips of each metal in each solution. The Mg strip will react in both solutions.

i.e., $3Mg_{(s)} + 2Al^{3+}{}_{(aq)} \longrightarrow 3Mg^{2+}{}_{(aq)} + 2Al_{(s)}$

and $Mg_{(s)} + Co^{2+}{}_{(aq)} \longrightarrow Mg^{2+}{}_{(aq)} + Co_{(s)}$

or $Mg_{(s)} + Fe^{2+}{}_{(aq)} \longrightarrow Mg^{2+}{}_{(aq)} + Fe_{(s)}$

The Zn strip will react in the $Co(NO_3)_{2\,(aq)}$ or $Fe(NO_3)_{2\,(aq)}$ but will NOT react in $Al(NO_3)_{3\,(aq)}$.

i.e., $Zn_{(s)} + Co^{2+}{}_{(aq)} \longrightarrow Zn^{2+}{}_{(aq)} + Co_{(s)}$

or $Zn_{(s)} + Fe^{2+}{}_{(aq)} \longrightarrow Zn^{2+}{}_{(aq)} + Fe_{(s)}$

The Sn strip will NOT react in any of the solutions.

GRADE 12 DIPLOMA EXAMINATION

Chemistry 30

January 1986

Alberta
EDUCATION

DUPLICATION OF THIS PAPER IN ANY MANNER OR ITS USE FOR PURPOSES OTHER THAN THOSE AUTHORIZED AND SCHEDULED BY ALBERTA EDUCATION IS STRICTLY PROHIBITED.

GRADE 12 DIPLOMA EXAMINATION
CHEMISTRY 30

DESCRIPTION

TIME: 2½ hours

Total possible marks: 70

This is a **CLOSED-BOOK** examination consisting of two parts:

PART A: 56 multiple-choice questions each with a value of 1 mark.

PART B: Three written-response questions for a total of 14 marks.

A chemistry data booklet is provided for your reference. Approved calculators may be used.

GENERAL INSTRUCTIONS

Fill in the information on the answer sheet as directed by the examiner.

For multiple-choice questions, read each carefully and decide which of the choices BEST completes the statement or answers the question. Locate that question number on the answer sheet and fill in the space that corresponds to your choice. USE AN HB PENCIL ONLY.

Example	**Answer Sheet**
This examination is for the subject area of	A B C D
A. Chemistry	● ② ③ ④
B. Biology	
C. Physics	
D. Mathematics	

If you wish to change an answer, please erase your first mark completely.

For written-response questions, read each carefully, show all your calculations, and write your answer in the space provided in the examination booklet.

NOTE: The perforated pages at the back of this booklet may be torn out and used for your rough work.

DO NOT FOLD EITHER THE ANSWER SHEET OR THE EXAMINATION BOOKLET

The presiding examiner will collect the answer sheet and examination booklet for transmission to Alberta Education.

JANUARY 1986

PART A

INSTRUCTIONS

There are 56 multiple-choice questions with a value of one mark each in this section of the examination. Use the separate answer sheet provided and follow the specific instructions given.

NOTE: The perforated pages at the back of this booklet may be torn out and used for your rough work.

WHEN YOU HAVE COMPLETED PART A, PROCEED DIRECTLY TO PART B

DO NOT TURN THE PAGE TO START THE EXAMINATION UNTIL TOLD TO DO SO BY THE PRESIDING EXAMINER.

1. When $H_2O_{(s)}$ at $-10°C$ is heated to $H_2O_{(l)}$ at 0°C, there is

   A. an increase in both potential energy and kinetic energy
   B. an increase in kinetic energy and no change in potential energy
   C. an increase in potential energy and a decrease in kinetic energy
   D. a decrease in potential energy and an increase in kinetic energy

2. The total energy of a substance is equal to

   A. $mc\Delta t$
   B. its heat of formation
   C. the sum of its kinetic and potential energies
   D. the difference between its kinetic and potential energies

3. The Law of Conservation of Energy states that

   A. spontaneous processes move toward a state of lower energy
   B. the total amount of energy in the universe remains constant
   C. the energy change for a chemical reaction is independent of the pathway
   D. heat energy always flows from a region of high temperature to one of low temperature

4. The heat of reaction for $Ca_{(s)} + \frac{1}{2}O_{2(g)} \longrightarrow CaO_{(s)}$ is

   A. -63.6 kJ
   B. -227 kJ
   C. -318 kJ
   D. -636 kJ

5. The most stable of the following compounds is

   A. $HF_{(g)}$
   B. $HI_{(g)}$
   C. $HBr_{(g)}$
   D. $HCl_{(g)}$

Use the following information to answer question 6.

I $2NaHCO_{3(s)} + 129.7\ kJ \longrightarrow Na_2CO_{3(s)} + CO_{2(g)} + H_2O_{(g)}$

II $2H_2O_{(l)} + O_{2(g)} \longrightarrow 2H_2O_{2(l)} \qquad \Delta H = +196.3\ kJ$

III $SiH_{4(g)} + 2O_{2(g)} \longrightarrow SiO_{2(s)} + 2H_2O_{(l)} \qquad \Delta H = -1517.5\ kJ$

IV $PbO_{(s)} + CO_{(g)} \longrightarrow Pb_{(s)} + CO_{2(g)} + 65.7\ kJ$

6. Which systems are endothermic?

A. I and II
B. I and III
C. II and IV
D. III and IV

Use the following information to answer question 7.

Carbon monoxide, a dangerous air pollutant, can be formed by the incomplete combustion of carbon, as represented by the equation: $2C_{(s)} + O_{2(g)} \longrightarrow 2CO_{(g)}$

7. The energy term for the balanced equation is conventionally written as

A. 110.5 kJ on the left side of the equation
B. 221.0 kJ on the left side of the equation
C. 110.5 kJ on the right side of the equation
D. 221.0 kJ on the right side of the equation

---

8. The equation which represents an endothermic process is

A. $CH_{4(g)} + 2O_{2(g)} \longrightarrow CO_{2(g)} + 2H_2O_{(g)}$

B. $2H_{2(g)} + O_{2(g)} \longrightarrow 2H_2O_{(l)}$

C. $C_4H_{10(l)} \longrightarrow C_4H_{10(g)}$

D. $Pb_{(l)} \longrightarrow Pb_{(s)}$

9. The reaction that would provide the greatest amount of heat is the

A. fission of $^{235}_{92}U$
B. combustion of $CH_{4(g)}$
C. sublimation of $CO_{2(s)}$
D. condensation of $H_2O_{(g)}$

Use the following information to answer question 10.

$H_2O(?) + SO_{3(g)} \longrightarrow H_2SO_{4(l)}$ $\quad \Delta H = -174$ kJ

The physical state of the water is not known.

10. The molar heat of formation for the water is

A. −40.8 kJ
B. −242 kJ
C. −286 kJ
D. −416 kJ

---

11. The heat of reaction for $2H_2S_{(g)} + 3O_{2(g)} \longrightarrow 2H_2O_{(l)} + 2SO_{2(g)}$ is

A. −562.7 kJ
B. −602.9 kJ
C. −1125.4 kJ
D. −1205.8 kJ

12. The heat of reaction for the equation $2NO_{(g)} + O_{2(g)} \longrightarrow 2NO_{2(g)}$ is

A. −113.2 kJ
B. −56.6 kJ
C. +56.6 kJ
D. +113.2 kJ

13. To raise the temperature of a calorimeter and its contents 1°C requires 5028 J. When 0.5 mol of fuel is burned in the calorimeter the temperature increases 4°C. Using these data, the heat of combustion for the fuel is

A. −100 kJ/mol
B. −60 kJ/mol
C. −40 kJ/mol
D. −20 kJ/mol

14. A bunsen burner that uses methane provides 500 kJ of energy for each mole of fuel burned. The number of moles of methane needed to heat 200 mL of water from 25°C to 50°C is

A. 0.042
B. 5.0
C. 21
D. 24

Use the following information to answer question 15.

$$X + 2T_2 \longrightarrow XT_4 + 83.8 \text{ kJ}$$

$$X + 3T_2 \longrightarrow XT_6 + 209.5 \text{ kJ}$$

15. The predicted ΔH value for $XT_4 + T_2 \longrightarrow XT_6$ is

A. +293.3 kJ
B. +125.7 kJ
C. −125.7 kJ
D. −293.3 kJ

Use the following information to answer question 16.

$$Ag_2O_{(s)} + 2HCl_{(g)} \longrightarrow 2AgCl_{(s)} + H_2O_{(l)} \qquad \Delta H = -324.7 \text{ kJ}$$

$$Ag_{(s)} + \tfrac{1}{2}Cl_{2(g)} \longrightarrow AgCl_{(s)} \qquad \Delta H = -127.0 \text{ kJ}$$

$$\tfrac{1}{2}H_{2(g)} + \tfrac{1}{2}Cl_{2(g)} \longrightarrow HCl_{(g)} \qquad \Delta H = -92.3 \text{ kJ}$$

$$H_{2(g)} + \tfrac{1}{2}O_{2(g)} \longrightarrow H_2O_{(l)} \qquad \Delta H = -285.9 \text{ kJ}$$

16. The heat of formation of silver oxide, $Ag_2O_{(s)}$, is

A. −829.8 kJ/mol
B. −30.6 kJ/mol
C. +4.1 kJ/mol
D. +30.6 kJ/mol

---

17. The calculated amount of energy required to consume 88.0 g of $CO_{2(g)}$ according to the equation $6CO_{2(g)} + 6H_2O_{(l)} + 2824\ kJ \longrightarrow C_6H_{12}O_{6(s)} + 6O_{2(g)}$ is

A. 471 kJ
B. 941 kJ
C. 1410 kJ
D. 3440 kJ

18. The amount of heat released from the combustion of six moles of methane, assuming that water vapor forms, is

A. 448.8 kJ
B. 802.3 kJ
C. 4813.8 kJ
D. 5711.5 kJ

19. During an experiment to classify substances as acids or bases, it is most important to determine the

A. pH of the solution
B. conductivity of the solution
C. concentration of the solution
D. percent dissociation of the solute

Use the following information to answer question 20.

A student wishes to identify a substance as acidic, basic, or neutral by using one or more of the following laboratory tests.

I conductivity of an aqueous solution of the substance
II reaction of the substance with metals below $2H^+/H_2$ in a standard reduction potential table
III reaction of the substance with red and blue litmus
IV color of an aqueous solution of the substance

20. As a minimum, the student needs to perform

A. III only
B. I and III only
C. III and IV only
D. I, II, and III only

21. The equation that represents a neutralization reaction is

A. $Zn_{(s)} + 2H^+_{(aq)} + 2Cl^-_{(aq)} \longrightarrow H_{2(g)} + Zn^{2+}_{(aq)} + 2Cl^-_{(aq)}$

B. $NaOH_{(s)} + H^+_{(aq)} + Cl^-_{(aq)} \longrightarrow Na^+_{(aq)} + H_2O_{(l)} + Cl^-_{(aq)}$

C. $4NO_{3(aq)}^- + 4H^-_{(aq)} \longrightarrow 4NO_{(g)} + 2H_2O_{(l)} + 3O_{2(g)}$

D. $2CH_3OH_{(l)} + 3O_{2(g)} \longrightarrow 2CO_{2(g)} + 4H_2O_{(l)}$

22. After adding sodium hydrogen sulphate to distilled water, a student should predict that

A. the pH would increase
B. the $[H_3O^+_{(aq)}]$ would increase
C. a basic solution would result
D. a neutral solution would result

23. Consider the equation $H_2CO_{3(aq)} + HPO_{4(aq)}^{2-} \rightleftharpoons HCO_{3(aq)}^- + H_2PO_{4(aq)}^-$. Which of the following pairs identifies the two acids for this reaction?

A. $HPO_{4(aq)}^{2-}$ and $HCO_{3(aq)}^-$

B. $H_2CO_{3(aq)}$ and $HCO_{3(aq)}^-$

C. $H_2CO_{3(aq)}$ and $H_2PO_{4(aq)}^-$

D. $HPO_{4(aq)}^{2-}$ and $H_2PO_{4(aq)}^-$

24. Since $HNO_{3(aq)}$ is a stronger acid than $HNO_{2(aq)}$, the

A. H^+ is more strongly bonded to NO_3^- than to NO_2^-
B. $NO_{2(aq)}^-$ ion is a stronger base than the $NO_{3(aq)}^-$ ion
C. $NO_{3(aq)}^-$ ion is a better proton acceptor than the $NO_{2(aq)}^-$ ion
D. $HNO_{2(aq)}$ molecule is a better proton donor than the $HNO_{3(aq)}$ molecule

25. For the reaction represented by $PO_{4(aq)}^{3-} + HCO_{3(aq)}^- \rightleftharpoons HPO_{4(aq)}^{2-} + CO_{3(aq)}^{2-}$, the strongest base is

A. $HPO_{4(aq)}^{2-}$

B. $HCO_{3(aq)}^-$

C. $PO_{4(aq)}^{3-}$

D. $CO_{3(aq)}^{2-}$

26. The pH of a solution is defined as the

A. log of the concentration of hydronium ions
B. negative log of the concentration of hydronium ions
C. log of the negative concentration of hydronium ions
D. negative log of the inverse concentration of hydronium ions

27. The pH of a 0.10 mol/L solution of oxalic acid is equal to

A. 1.00
B. 1.28
C. 2.72
D. 5.30

Use the following information to answer question 28.

The addition of various indicators to a nitric acid solution produces the following results:

Test Tube	Indicator Added	Color of Solution
1	orange IV	yellow
2	methyl orange	yellow
3	bromocresol green	blue
4	methyl red	orange
5	bromothymol blue	yellow

28. The most probable concentration for the solution is

A. 4.0×10^{-3} mol/L
B. 8.0×10^{-5} mol/L
C. 2.5×10^{-6} mol/L
D. 3.2×10^{-7} mol/L

---

29. The equation which represents the dissociation of $HS^-_{(aq)}$ is

A. $HS^-_{(aq)} + H_2O_{(l)} \rightleftharpoons H_2S_{(aq)} + OH^-_{(aq)}$

B. $HS^-_{(aq)} + H_3O^+_{(aq)} \rightleftharpoons H_2S_{(aq)} + H_2O_{(l)}$

C. $HS^-_{(aq)} + H_2O_{(l)} \rightleftharpoons S^{2-}_{(aq)} + H_3O^+_{(aq)}$

D. $HS^-_{(aq)} + H_2O_{(l)} \rightleftharpoons H_{2(g)} + S^{2-}_{(aq)} + OH^-_{(aq)}$

30. The $[H_3O^+_{(aq)}]$ of 0.10 mol/L lactic acid, $CH_3CHOHCOOH_{(aq)}$, is 4.0×10^{-3} mol/L. The per cent of the acid that is dissociated is

A. 4.0
B. 0.25
C. 0.080
D. 0.040

31. A property common to acidic and basic solutions is that they both

A. have a bitter taste
B. have a K_w of 1×10^{-14} mol^2/L^2
C. react with calcium metal to form $H_{2(g)}$
D. have hydroxide ion concentrations of 1×10^{-7} mol/L

32. The $[H_3O^+_{(aq)}]$ in 2 L of solution prepared by dissolving 1.12 g of $KOH_{(s)}$ in distilled water is

A. 1×10^{-1} mol/L
B. 1×10^{-2} mol/L
C. 1×10^{-12} mol/L
D. 1×10^{-13} mol/L

33. Given 0.10 mol/L solutions of $HOCl_{(aq)}$, $HF_{(aq)}$, $HCN_{(aq)}$, and $CH_3COOH_{(aq)}$, the solution with the largest $[OH^-_{(aq)}]$ is

A. $HF_{(aq)}$
B. $HCN_{(aq)}$
C. $HOCl_{(aq)}$
D. $CH_3COOH_{(aq)}$

Use the following information to answer question 34.

A student dissolved 36.0 g of $NaHSO_{4(s)}$ in enough $H_2O_{(l)}$ to make 500.0 mL of solution and then titrated 50.0 mL of this solution with 2.00 mol/L $KOH_{(aq)}$.

34. The volume of $KOH_{(aq)}$ needed to neutralize 50.0 mL of $NaHSO_{4(aq)}$ is

A. 45.0 mL
B. 30.0 mL
C. 15.0 mL
D. 7.50 mL

Use the following information to answer question 35.

An unknown solution conducts electricity. As the solution is titrated with $Ba(OH)_{2(aq)}$, the resulting mixture turns cloudy and its conductivity decreases.

35. The unknown solution could be

A. $H_2SO_{4(aq)}$
B. $NaOH_{(aq)}$
C. $HCl_{(aq)}$
D. $HBr_{(aq)}$

---

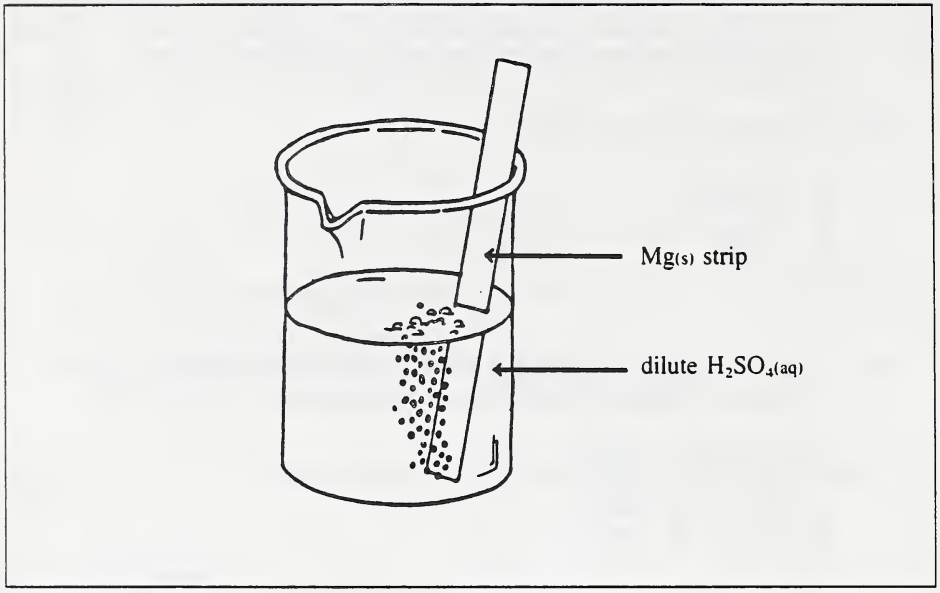
36. A solution is prepared by adding 4.99 L of 2.00 mol/L $HCl_{(aq)}$ to 5.00 L of 2.00 mol/L $NaOH_{(aq)}$. The $H_3O^+_{(aq)}$ concentration of the mixture will be

A. 5.0×10^{-12} mol/L
B. 2.0×10^{-4} mol/L
C. 2.0×10^{-2} mol/L
D. 1.0×10^{-1} mol/L

37. If 50.0 mL of 0.40 mol/L $HCl_{(aq)}$ were added to 100.0 mL of 0.20 mol/L $LiOH_{(aq)}$, the final solution would

A. be neutral
B. have a sour taste
C. have a bitter taste
D. change colorless phenolphthalein to pink

Use the following information to answer question 38.



38. The best conclusion is that the $Mg_{(s)}$ strip

A. loses mass
B. gains mass
C. undergoes reduction
D. produces magnesium sulphide

---

39. An example of reduction is

A. $I \longrightarrow I^-$
B. $I^- \longrightarrow I$
C. $Fe \longrightarrow Fe^{2+}$
D. $Fe^{2+} \longrightarrow Fe^{3+}$

40. $Cu_{(s)}$ is placed in 1.0 mol/L $AgNO_{3(aq)}$. The oxidizing agent is

A. $Ag_{(s)}$
B. $Cu_{(s)}$
C. $Ag^{+}_{(aq)}$
D. $Cu^{2+}_{(aq)}$

41. The net equation representing the reaction between chlorine gas and aqueous sodium iodide is

A. $2Cl^{-}_{(aq)} + I_{2(s)} \longrightarrow Cl_{2(g)} + 2I^{-}_{(s)}$

B. $Na^{+}_{(aq)} + Cl_{2(g)} \longrightarrow Na_{(s)} + 2Cl^{-}_{(aq)}$

C. $Cl_{2(g)} + 2I^{-}_{(aq)} \longrightarrow 2Cl^{-}_{(aq)} + I_{2(s)}$

D. $Na^{+}_{(aq)} + I_{2(s)} + 2Cl^{-}_{(aq)} \longrightarrow Na_{(s)} + 2I^{-}_{(aq)} + Cl_{2(g)}$

42. In which species does S have the lowest oxidation number?

A. $H_2S_2O_7$

B. $S_2O_3^{2-}$

C. $S_4O_6^{2-}$

D. $KHSO_3$

43. An increase in oxidation number indicates a species

A. is reduced
B. gains electrons
C. loses electrons
D. is an oxidizing agent

44. For this equation, $MnO^{-}_{4(aq)} + C_2O_4^{2-}{}_{(aq)} + H^{+}_{(aq)} \longrightarrow Mn^{2+}_{(aq)} + H_2O_{(l)} + CO_{2(g)}$, the oxidizing agent and reducing agent, respectively, are

A. $H^{+}_{(aq)}$ and $H_2O_{(l)}$
B. $Mn^{2+}_{(aq)}$ and $CO_{2(g)}$
C. $MnO^{-}_{4(aq)}$ and $Mn^{2+}_{(aq)}$
D. $MnO^{-}_{4(aq)}$ and $C_2O_4^{2-}{}_{(aq)}$

45. For a balanced redox equation, the substances oxidized and reduced must exchange

A. equal numbers of electrons
B. equal numbers of electrons per atom
C. equal numbers of electrons per formula unit
D. enough electrons so that their oxidation numbers become equal

Use the following information to answer question 46.

$MnO_{4(aq)}^{-} + SO_{2(g)} + H_2O_{(l)} \longrightarrow Mn^{2+}_{(aq)} + SO_{4}^{2-}{}_{(aq)} + H^{+}_{(aq)}$

is an unbalanced equation.

46. When the equation is balanced with whole numbers, the sum of the coefficients is

A. 10
B. 16
C. 18
D. 20

---

47. 20.0 mL of acidified $MnO_{4(aq)}^{-}$ is titrated to its endpoint with 40.0 mL of 0.200 mol/L $Sn^{2+}_{(aq)}$. The molar concentration of the $MnO_{4(aq)}^{-}$ is

A. 0.160 mol/L
B. 0.400 mol/L
C. 0.640 mol/L
D. 1.00 mol/L

48. $AlCl_{3(l)}$ undergoes electrolysis in an electrolytic cell and 5.40 g of $Al_{(l)}$ are collected at the cathode. The mass of $Cl_{2(g)}$ collected at the anode is

A. 7.10 g
B. 14.2 g
C. 21.3 g
D. 42.6 g

Use the following information to answer question 49.

As part of a laboratory procedure a student recorded observations after placing strips of metal into aqueous solutions according to the following combinations.

Metals \ Ions	$Be^{2+}_{(aq)}$	$Cd^{2+}_{(aq)}$	$Ra^{2+}_{(aq)}$	$V^{2+}_{(aq)}$
$Be_{(s)}$		reaction	no change	reaction
$Cd_{(s)}$	no change		no change	no change
$Ra_{(s)}$	reaction	reaction		reaction
$V_{(s)}$	no change	reaction	no change	

49. The grouping in which the oxidizing agents are arranged from strongest to weakest is

A. $Cd_{(s)}$, $V_{(s)}$, $Be_{(s)}$, $Ra_{(s)}$
B. $Ra_{(s)}$, $Be_{(s)}$, $V_{(s)}$, $Cd_{(s)}$
C. $Ra^{2+}_{(aq)}$, $Be^{2+}_{(aq)}$, $V^{2+}_{(aq)}$, $Cd^{2+}_{(aq)}$
D. $Cd^{2+}_{(aq)}$, $V^{2+}_{(aq)}$, $Be^{2+}_{(aq)}$, $Ra^{2+}_{(aq)}$

---

50. Negative $E°$ values for reduction half-reactions indicate

A. less tendency than the reference half-reaction to undergo reduction
B. that these reducing agents lose electrons less readily than does $H_{2(g)}$
C. greater tendency than the reference half-reaction to undergo reduction
D. that these oxidizing agents gain electrons more readily than does $H^{+}_{(aq)}$

51. When solid copper is immersed in a solution of silver nitrate all of the following occur EXCEPT

A. the solution turns blue
B. silver metal is produced
C. the mass of Cu increases
D. the concentration of silver ions decreases

Use the following information to answer question 52.

The reaction $2X^- + R \longrightarrow R^{2-} + 2X$ takes place spontaneously generating a voltage of 1.20 V.

52. If the $E°$ value for the half-reaction $2X^- \longrightarrow 2X + 2e^-$ is -0.80 V, the potential for the half-equation $R + 2e^- \longrightarrow R^{2-}$ would be

A. +2.00 V
B. +0.40 V
C. +0.20 V
D. −0.40 V

---

53. The species that react spontaneously are

A. $Cr^{3+}(aq)$, $H_2O(l)$, $Co^{2+}(aq)$

B. $H_2SO_3(aq)$, $H_2O(l)$, $Cl_2(g)$

C. $I_2(s)$, $H^+(aq)$, $NO_3^-(aq)$

D. $I_2(s)$, $Br^-(aq)$

Use the following information to answer question 54.

Two electrolytic cells are set up in a circuit so that they receive the same current for the same length of time. One half-reaction for each of the two cells is:

Cell 1: $Al^{3+}(l) + 3e^- \longrightarrow Al(l)$

Cell 2: $Na^+(l) + e^- \longrightarrow Na(l)$

54. If 1.38 g of sodium are produced, how many moles of aluminum are produced?

A. 0.0200 mol
B. 0.0300 mol
C. 0.0500 mol
D. 0.0600 mol

Use the following information to answer question 55.

Given the statements:

I Anions migrate to the anode and cations migrate to the cathode.

II Electrons flow from the anode to the cathode.

III Oxidation occurs at the anode and reduction occurs at the cathode.

55. Both electrochemical and electrolytic cells are described by

A. I only
B. II only
C. I and II only
D. I, II, and III

---

56. When the surface of a tin can is scratched, the exposed iron rusts rapidly. One explanation is that an electrochemical process occurs in which

A. tin is the anode
B. iron is the anode
C. tin is the cathode
D. iron is the cathode

YOU HAVE NOW COMPLETED THE MULTIPLE-CHOICE SECTION OF THE EXAMINATION. PLEASE PROCEED TO THE NEXT PAGE AND ANSWER THE WRITTEN-RESPONSE QUESTIONS IN PART B.

PART B

INSTRUCTIONS

Please write your answers in the examination booklet as neatly as possible.

Marks will be awarded for pertinent explanations, calculations, formulas, and answers. Answers must be given to the appropriate number of significant digits.

NOTE: The perforated pages at the back of this booklet may be torn out and used for your rough work.

TOTAL MARKS: 14

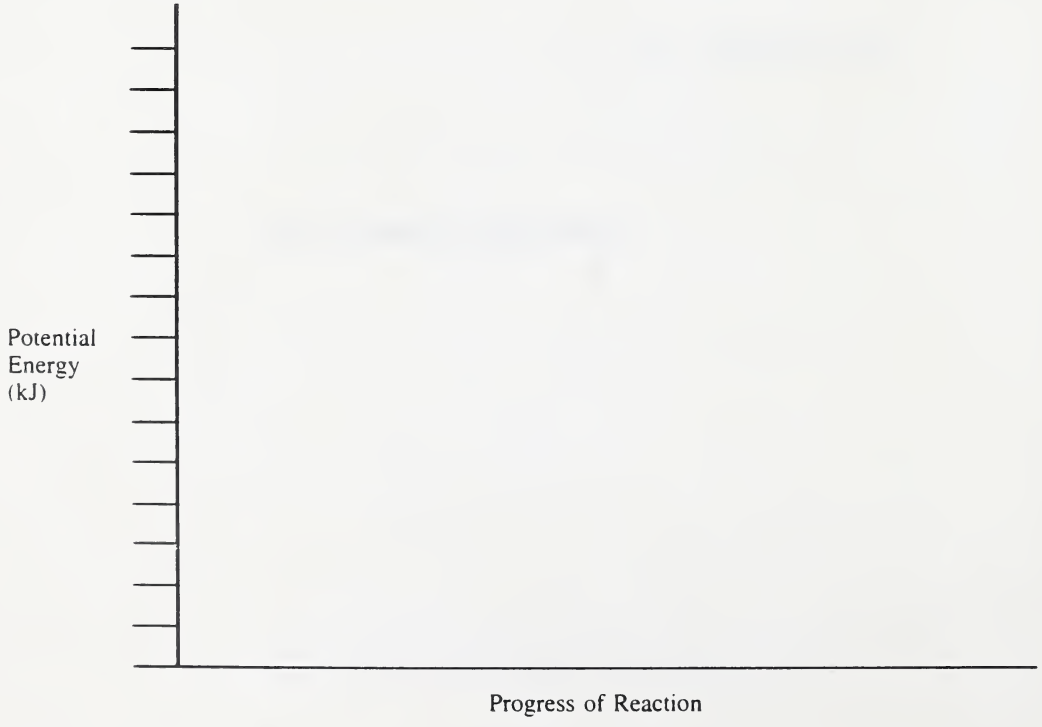
START PART B IMMEDIATELY

(5 marks) 1. Aluminum reacts with iron (III) oxide to form iron metal and aluminum oxide. Place numerical values on the axis provided and draw a labelled potential energy diagram for this reaction. Write a balanced equation and show your calculations in the space provided.

Balanced equation:

Calculations:

Diagram:



Use the following information to answer question 2.

Three hypothetical acids HX, HY, and HZ and their conjugate bases X^-, Y^-, and Z^- gave the following information when tested for reaction.

$HX + Y^- \rightleftharpoons HY + X^-$ (equilibrium concentrations favor products)

$HX + Z^- \rightleftharpoons HZ + X^-$ (equilibrium concentrations favor reactants)

(4 marks) 2. a. List the acids with their conjugate bases from strongest acid to weakest.

strongest acid 1. _____ its conjugate base _____

2. _____ its conjugate base _____

3. _____ its conjugate base _____

b. Which ion would form the weakest bond with hydrogen ions?

c. Write a Brønsted-Lowry equation for the reaction of HY with Z^- and predict which side is favored at equilibrium.

equation:

_____

equilibrium concentrations favor _____

Use the following information to answer question 3.

> Scientists isolated a previously undiscovered metal of which they managed to produce a few thin strips. They predicted that the metal would fit between tin and lead on the Table of Standard Electrode Potentials. Assume they give you the metal strips and you have access to a lab with various common metals and solutions of their ions. Use the symbol $M_{(s)}$ to represent the new metal.

(5 marks) 3. a. List 2 steps you could use as an experimental procedure that would test the scientists' prediction.

Step 1. _____

_____

Step 2. _____

_____

b. Assume that the scientists' prediction was verified and state the observations that you would expect for each step.

Step 1. _____

Step 2. _____

c. Assume the scientists' prediction was verified and write a possible balanced equation for each reaction that occurred involving the unknown metal.

d. Give a probable $E°$ value for the reduction half-reaction of the metal.

YOU HAVE NOW COMPLETED THE EXAMINATION. IF YOU HAVE TIME, YOU MAY WISH TO GO BACK AND CHECK YOUR ANSWERS.

1. A Potential energy increases during this phase change $H_2O_{(s)} \longrightarrow H_2O_{(l)}$

Kinetic energy increases during the temperature change from -10°C to 0°C.

2. C refer to pages 85, 232 of text

3. B refer to page 232 (Law of Conservation of Energy)

4. D ΔH = (heat of products) - (heat of reactants)

= -635.5 kJ/mol - Ø kJ/mol
= -635.5 kJ/mol

5. A Fluorine has the highest electronegativity thus it will form the most stable bond with hydrogen compared to the other elements in this list.

6. A I absorbs 129.7 kJ
II a positive value for ΔH indicates heat is absorbed.

7. D ΔH = -110.5 kJ/mol (exothermic)

since there are 2 mols of $CO_{(g)}$ produced the total heat released is 221.0 kJ. This is written into the equation on the right side of the equation:

$2C_{(s)} + O_2(g) \longrightarrow 2CO_{(g)} + 221.0$ kJ

8. C refer to data booklet for the heats of formation. Use the formula

ΔH = (heat of products) - (heat of reactants)

In A ΔH = -802.3 kJ (exothermic)
In B ΔH = -571.8 kJ (exothermic)
In C process is endothermic since any substance changing from liquid to gas requires energy.
In D process is exothermic since heat is liberated when a liquid changes to a solid.

9. A. nuclear reactions release much more heat compared to chemical reactions or phase changes.

10. B If the state of water is a liquid ($H_2O_{(l)}$) then the heat of the reactions is:

$\Delta H = (-811.3 \text{ kJ}) - (-285.9 \text{ kJ} - 395.2 \text{ kJ})$

$= -130.2 \text{ kJ}$

If the state of the water is a gas:

$\Delta H = (-811.3 \text{ kJ}) - (-241.8 \text{ kJ} - 395.2 \text{ kJ})$

$= -174.3 \text{ kJ}$

11. C use ΔH = (heat products) - (heat reactants)

12. A see data booklet (heats of formation)

13. C heat released on burning the fuel is

$$\frac{(5028 \text{ J})\ (4^\circ\text{C})}{1^\circ\text{C}} = 20112 \text{ J} = 20.112 \text{ kJ}$$

$$\text{heat released per mol} = \frac{20.112 \text{ kJ}}{0.5 \text{ mol}} = 40.224 \text{ kJ/mol}$$

$= 40 \text{ kJ/mol}$

(correct to 1 significant digit)

$\therefore$ heat of comberstion = -40 kJ/mol
(negative since heat is released).

14. A Find the heat required

$H = m\Delta Tc$

$H = (200 \text{ g})\ (50^\circ\text{C} - 25^\circ\text{C})\ (4.19 \text{ J/g}^\circ\text{C})$

$= 20950 \text{ J}$

$= 20.95 \text{ kJ}$

number of moles of methane is

$$\frac{20.95 \text{ kJ}}{500 \text{ kJ/mol}} = 0.042 \text{ mol}$$

15. C Add the two equations to get the net equation:

$XT_4 + 83.8\ kJ \longrightarrow X + 2T_2$

$X + 3T_2 \longrightarrow XT_6 + 209.5\ kJ$

$XT_4 + T_2 \longrightarrow XT_6 + 125.7\ kJ$

(note the cancelled terms on each side)

exothermic reaction thus $\Delta H = -125.7$ kJ

16. B Let the unknown heat of formation per mole of $Ag_2O_{(s)}$ equal x.
Using the formula H = (heat products) - (heat reactants)

$-324.7\ kJ = [2(-127\ kJ) + (-285.9\ kJ)] - [(184.6\ kJ) + (x)]$

$-x = -324.7\ kJ - 184.6\ kJ + 539.9\ kJ$

$x = -30.6\ kJ$

17. B number of moles of $CO_{2(g)} = \frac{88\ g}{44\ g/mol} = 2$ mol

Since 6 mol of $CO_{2(g)}$ requires 2824 kJ thus 2 mol of $CO_{2(g)}$ requires $\frac{2824\ kJ}{3} = 941$ kJ

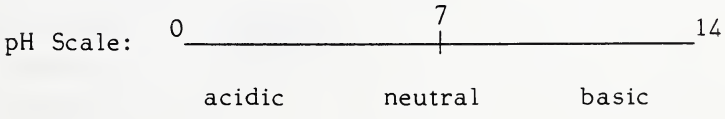
18. C $CH_{4(g)} + 2O_{2(g)} \longrightarrow CO_{2(g)} + 2H_2O_{(g)}$

$\Delta H = [(-393.5\ kJ/mol) + 2\ (-241.8\ kJ/mol] - [-74.8\ kJ/mol]$

$\Delta H = -802.3$ kJ/mol

$\therefore$ heat released for 6 mol = 6(802.3 kJ) = 4813.8 kJ

19. A pH would be an important factor in the classification of acids and bases since it is a measure of the concentration of the hydrogen ion. The degree of acidity of basicity can be measured by a pH scale.



20. A. Method III is the minimum a student needs to perform. Litmus paper is one of the easiest and most accurate methods of identifying acids and bases.

*Red litmus remains red in the presence of an acid.

*Red litmus turns blue in the presence of a base.

*Blue litmus remains blue in the presence of a base.

*Blue litmus turns red in the presence of an acid.

21. B A neutralization reaction consists of an acid and a base reacting together to produce a salt and water.

$$\underbrace{NaOH_{(s)}}_{\text{sodium hydroxide (Base)}} + \underbrace{H^+_{(aq)} + Cl^-_{(aq)}}_{\text{hydrochloric acid dissociated in solution}} \longrightarrow \underbrace{Na^+_{(aq)} + Cl^-_{(aq)}}_{\text{Salt (sodium chloride) dissociates in solution}}$$

$$+ H_2O_{(l)}$$

(water)

22. B. Sodium hydrogen sulfate added to water would supply extra hydrogen ions. The hydrogen ions would become hydrated in the presence of water to form H_3O^+ (hydronium ions). Thus the concentration of the hydronium ions would increase.

23. C Recall that acids donate protons and bases accept protons.

net equation: $\underset{\text{ACID}}{H_2CO_{3(aq)}} + HPO_4^{2-}{}_{(aq)} \rightleftharpoons HCO_3^-{}_{(aq)} + \underset{\text{ACID}}{H_2PO_4^-{}_{(aq)}}$

Forward Reaction : H_2CO_3 (acid donates a proton to HPO_4^{2-} which becomes $H_2PO_4^-$ after gaining the proton.

Reverse Reaction : $H_2PO_4^-$ is the acid because it donates a proton to HCO_3^- which becomes H_2CO_3 after gaining a proton.

24. B Recall that a strong acid has a weak conjugate base and vice-versa.

Since $HNO_{3(aq)}$ is a strong acid it would have a weak conjugate base (NO_3^-).

Since $HNO_{2(aq)}$ is a weaker acid than HNO_3 it would have a strong conjugate base (NO_2^-).

Therefore, the statement "$NO_{2(aq)}^-$ ion is a stronger base than the $NO_{3(aq)}^-$ ion" is correct.

25. C Identify the bases in the net equation. Recall that bases accept protons.

$$PO_4^{3-}(aq) + HCO_3^-(aq) \rightleftharpoons HPO_4^{2-}(aq) + CO_3^{2-}(aq)$$

BASE BASE

See the chemistry data booklet (Relative Strengths of Acids and Bases).

Determine which is the stronger base (PO_4^{3-} or CO_3^{2-}) by looking at the chart of increasing base strength. The chart indicates that $PO_{4(aq)}^{3-}$ is the stronger base.

26. B $pH = -\log [H^+]$

or

$pH = -\log [H_3O^+]$

see Lesson 19 p. 6 sample problem #4

27. B See Chemistry data booklet section (Relative Strengths of Acids and Bases).

Calculate the % reaction of oxalic acid with water:

$\frac{53}{100} \times 0.10 \text{ mol/L} = 0.053 \text{ mol/L}$

$pH = \log [H^+]$

$\therefore pH = -\log [0.053]$

$pH = 1.28$

28. C since methyl red is orange pH is between 4.8 and 6.0 which is 5.4. The concentration is given by

$[H^+]$ = antilog (-pH)
= antilog (-5.4)
= 3.98×10^{-6}

The "best" answer is C.

29. C $HS^-_{(aq)} + H_2O_{(l)} \rightleftharpoons S^{2-}_{(aq)} + H_3O^+_{(aq)}$

HS^- in solution will act as an acid thereby giving up its proton to water and becoming S^{2-}. When water gains the proton it becomes a hydronium ion.

30. A Calculate the % dissociation of lactic acid

$$\frac{4.0 \times 10^{-3} \text{ mol/L}}{0.10 \text{ mol/L}} = 0.04 = 4\%$$

31. B $Kw = [H^+]\,[OH^-] = 1 \times 10^{-14} \text{ mol}^2/\text{L}^2$

since $[H^+] = 1 \times 10^{-7}$ mol/L and $[OH^-] = 1 \times 10^{-7}$ mol/L in pure water at 25°C.

see text p. 292 and p. 293

32. C Determine the number of moles in 1.12 g of KOH

$$\frac{1.12 \text{ g}}{56.11 \text{ g/mol}} = 0.02 \text{ mol KOH}$$

$$C = \frac{\text{mol}}{\text{L}} = \frac{0.02 \text{ mol}}{2 \text{ L}} = 0.01 \text{ mol/L}$$

$Kw = [H_3O^+]\,[OH^-]$

$$\therefore [H_3O^+] = \frac{kw}{[OH^-]} = \frac{1 \times 10^{-14} \text{ mol}^2/\text{L}^2}{0.01 \text{ mol/L}} =$$

1×10^{-12} mol/L

33. B The weakest acid will have the highest $[OH^-_{(aq)}]$. See chemistry data booklet (Relative Strengths of Acids and Bases).

HCN is the weakest acid (has the smallest KA) and therefore it will have the highest $[OH^-_{(aq)}]$.

34. C $NaHSO_4$ $\frac{36.0\ g}{120.06\ g/mol} = 0.300\ mol$

There are 0.300 mol of $NaHSO_4$. There are also 0.300 mol of KOH because the mole ratio of $NaHSO_4$ to KOH is 1:1.

Volume (KOH) = $\frac{0.300\ mol}{2.00\ mol/L} = 0.150\ L$ or 15 mL

35. A $Ba^{+2}_{(aq)} + 2OH^-_{(aq)} + 2H^+_{(aq)} + SO_4^{-2}{}_{(aq)} \longrightarrow$

$BaSO_{4(s)} + 2H_2O_{(l)}$

white ppt
(barium
sulfate)

As a solution of barium hydroxide, $Ba(OH)_2$, is mixed with a solution of sulfuric acid, $H_2SO_{4(aq)}$, a white precipitate (barium sulfate) forms and the electrical conductivity decreases markedly. This is because barium sulfate remains as a precipitate and is therefore a poor electrolyte.

36. A $HCl_{(aq)}$ 4.99 L x 2.00 mol/L = 9.98 mol

$NaOH_{(aq)}$ 5 L x 2.00 mol/L = 10.0 mol

Excess $OH^-_{(aq)}$ = 10.0 mol -9.98 mol = 0.02 mol

concentration = $\frac{0.02\ mol}{9.99\ L} = 2 \times 10^{-3}\ mol/L$

$[H_3O^+_{(aq)}] = \frac{10^{-14}\ mol^2/L^2}{2 \times 10^{-3}\ mol/L} = 5.0 \times 10^{-12}\ mol/L$

37. A HCl 0.050 L x 0.40 mol/L = 0.02 mol
NaOH 0.100 L x 0.20 mol/L = 0.02 mol

HCl concentration = $\frac{0.02\ mol}{0.15\ L} = 0.133\ mol/L$

NaOH concentration = $\frac{0.02\ mol}{0.15\ L} = 0.133\ mol/L$

Concentrations are equal therefore neutralization occurs.

0.133 mol/L - 0.133 mol/L = 0

"Neutral Solution"

38. A Mg (magnesium) is a strong reducing agent therefore it would be oxidized readily.

$Mg_{(s)} \longrightarrow Mg^{2+} + 2e^-$

Consequently, the magnesium metal strip would lose some mass. As magnesium metal loses electrons magnesium ions go into the dilute sulfuric acid solution.

39. A Reduction is the gaining of electrons. Write the redox reactions showing electron distribution.

a. $I + e^- \longrightarrow I^-$ (electron gain - reduction)

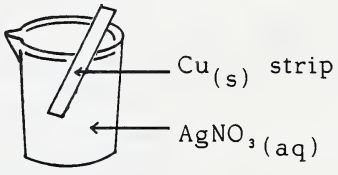
nonmetals gain electrons to become negative ions

b. $I^- \longrightarrow I + e^-$ (electron loss - oxidation)

c. $Fe \longrightarrow Fe^{2+} + 2e^-$ (electron loss - oxidation)

d. $Fe^{2+} \longrightarrow Fe^{3+} + e^-$ (electron loss - oxidation)

40. C



An oxidizing agent causes oxidation but undergoes reduction.

Look at the standard electrode potentials chart in the chemistry data booklet.

You can see that Ag^+ is a strong oxidizing agent. Therefore, it will be reduced.

$2\,(Ag^+_{(aq)} + e^- \longrightarrow Ag_{(s)})$ (reduction)

$Cu_{(s)} \longrightarrow Cu^{2+} + 2e^-$ (oxidation)

net equation: $2Ag^+_{(aq)} + Cu_{(s)} \longrightarrow 2Ag_{(s)} + Cu^{2+}_{(aq)}$

41. C Choose the two half-reactions from the table of (Standard Electrode Potentials) in your chemistry data booklet.

$$Cl_{2(g)} + 2e^- \longrightarrow 2Cl^-_{(aq)}$$
$$2I^-_{(aq)} \longrightarrow I_{2(s)} + 2e^-$$

$$Cl_{2(g)} + 2I^-_{(aq)} \longrightarrow 2Cl^-_{(aq)} + I_{2(s)}$$

42. B Follow the rules for determining oxidation numbers p. 339 (text).

Keep in mind that the oxidation number for oxygen is -2 in almost all of its compounds and the oxidation number for hydrogen is +1 in almost all of its compounds.

43. C An increase in oxidation number indicates that a species is undergoing oxidation or a loss of electrons.

see p. 1, Lesson 15.

44. D see p. 6, Lesson 15 for definition of oxidizing agents and reducing agents:

Oxidizing Agent:
- is reduced or gains electrons
- has a reduction in the oxidation number.

Reducing Agent:
- is oxidized or loses electrons
- has a gain in the oxidation number.

net charge $\quad +7 \quad -8 \qquad +6 \quad -8 \qquad +1$

$$MnO_4^-{}_{(aq)} + C_2O_4^{2-}{}_{(aq)} + H^+{}_{(aq)}$$

oxidation number $\quad +7 \quad -2 \qquad +3 \quad -2 \qquad +1$

net charge $\quad +2 \qquad +2 \quad -2 \quad +4 \quad -4$

$$\longrightarrow Mn^{2+}{}_{(aq)} + H_2O_{(l)} + CO_{2(g)}$$

oxidation number $\quad +2 \qquad +2 \quad -2 \quad +4 \quad -2$

oxidizing agent: (reduced) MnO_4^- has a reduction in oxidation number.

reducing agent: (oxidized) $C_2O_4^{2-}$ has an increase in oxidation number.

45. A see text p. 312-313

46. D Balance the given equation by following the rules given in the text p. 334-338 "Balancing oxidation-reduction equations."

You will find that method III "Devising Half-Reactions" will be the best method of balancing the equations.

Two half-reactions can be used

$$10e^- + 16H^+_{(aq)} + 2MnO^-_{4(aq)} \longrightarrow 2Mn^{2+}_{(aq)} + 8H_2O_{(l)}$$

$$10H_2O_{(l)} + 5SO_{2(g)} \longrightarrow 5SO^{2-}_{4(aq)} + 2OH^+_{(aq)} + 10e^-$$

$$2MnO^-_{4(aq)} + 5SO_{2(g)} + 2H_2O_{(l)} \longrightarrow 2Mn^{2+}_{(aq)} + 5SO^{2-}_{4(aq)} + 4H^+_{(aq)}$$

The sum of the coefficients in the balanced equation is 20.

47. A Use half reactions to obtain the balanced equation:

$$5Sn^{2+}_{(aq)} + 2MnO^-_{4(aq)} + 16H^+_{(aq)} \longrightarrow 5Sn^{4+}_{(aq)} + 2Mn^{2+}_{(aq)} + 8H_2O_{(l)}$$

determine the number of moles of $SN^{2+}_{(aq)}$:

$$(0.200 \text{ mol/L})\ (0.040 \text{ L}) = 8.00 \times 10^{-3} \text{ mol}$$

mole ratio is 5:2 therefore there were

$$(8.00 \times 10^{-3} \text{ mol})\ (\tfrac{2}{5}) = 3.20 \times 10^{-3} \text{ mol } MnO^-_{4(aq)}$$

$$\text{concentration} = \frac{3.20 \times 10^{-3} \text{ mol}}{0.0200 \text{ L}} = 0.160 \text{ mol/L}$$

48. C $$\text{number of moles of Al} = \frac{5.40 \text{ g}}{26.98 \text{ g/mol}} = 0.200 \text{ mol}$$

Balance equation: $2AlCl_{3(l)} \longrightarrow 2Al_{(l)} + 3Cl_{2(g)}$

mole ratio is 3:2 therefore

$(0.200 \text{ mol}) \left(\frac{3}{2}\right) = 0.300 \text{ mol of } Cl_{2(g)}$ is produced.

mass = (0.300 mol) (70.90 g/mol) = 21.27 g

or 21.3 g (correct to 3 significant figures)

49. D $Cd^{2+}_{(aq)}$ reacts with all three metals therefore it is first in the list.

50. A refer to pp 323, 324 of text

51. C $Cu_{(s)} \longrightarrow Cu^{2+}_{(aq)} + 2e^-$ $E^0 = -0.34$ V

$2Ag^+_{(aq)} + 2e^- \longrightarrow 2Ag_{(s)}$ $E^0 = +0.80$ V

$Cu_{(s)} + 2Ag^+_{(aq)} \longrightarrow Cu^{2+}_{(aq)} + 2Ag_{(s)}$ $E^0 = 0.46$ V

reaction will proceed

52. A $2x^- \longrightarrow 2x + 2e^-$ $E^0 = -0.80$ V

$R + 2e^- \longrightarrow R^{2-}$ $E^0 = x$

$2x^- + R \longrightarrow R^{2-} + 2x$ $E^0 = 1.20$ V

$\therefore x = 1.20 \text{ V} - (-0.80 \text{ V}) = 2.00 \text{ V}$

53. B use the half reactions to find which ones will produce a positive voltage

54. A mole ratio is 3 to 1

number of moles of sodium $= \frac{1.38 \text{ g}}{22.99 \text{ g/mol}} =$ 0.0600 mol

$\therefore$ number of moles of Al $= \frac{0.0600 \text{ mol}}{3} = 0.0200$ mol

55. D refer to text pp 311-315 and 330-334

56. B refer to text pp 329-330

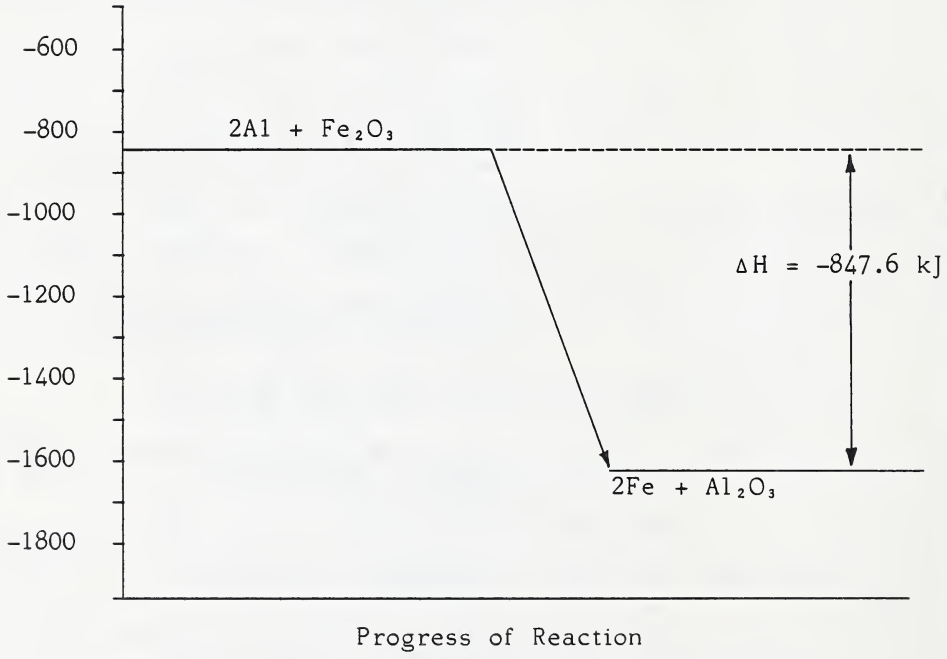
SAMPLE ANSWERS TO THE WRITTEN-RESPONSE SECTION

Note: The responses that follow represent ONE approach to each of the problems. During the diploma examination marking session, provision is made for considering the various approaches students may have used.

(5 marks) 1. Aluminum reacts with iron (III) oxide to form iron metal and aluminum oxide. Place numerical values on the axis provided and draw a labelled potential energy diagram for this reaction. Write a balanced equation and show your calculations in the space provided.

Balanced equation: $2Al(s) + Fe_2O_3(s) \longrightarrow Al_2O_3(s) + 2Fe(s)$

calculations: $\Delta H = (-1669.8\ kJ) - (-822.2\ kJ)$
$= -847.6\ kJ$



(4 marks) 2. a. List the acids with their conjugate bases from strongest acid to weakest.

- HZ and Z^-
- HX and X^-
- HY and Y^-

b. Which ion would form the weakest bond with hydrogen ions?

- Z^-

2. c. Write a Brønsted-Lowry equation for the reaction of HY with Z^- and predict which side is favored at equilibrium.

$- HY + Z^- \rightleftharpoons HZ + Y^-$

d. equilibrium concentrations favor reactants

(5 marks) 3. a. List 2 steps you could use as an experimental procedure that would test the scientists' prediction.

Procedure

1. Place unknown metal in a Pb^{2+} solution
2. Place unknown metal in a Sn^{2+} solution

b. Assume that the scientists' prediction was verified and state the observations that you would expect for each step.

Observation

1. The metal reacts with Pb^{2+} ions and Pb(s) deposits in the metal.
2. No visible reaction occurs.

c. Assume the scientists' prediction was verified and write a possible balanced equation for each reaction that occurred involving the unknown metal.

equation: $M(s) + Pb^{2+}(ag) \longrightarrow M^{2+}(aq) + Pb(s)$

d. Give a probable E^0 value for the reduction half-reaction of the metal.

E^0 value: between -0.13 and -0.14

A LESSON RECORD FORM MUST BE COMPLETED FOR EVERY LESSON SUBMITTED FOR CORRECTION, AS ILLUSTRATED BELOW

A Lesson Record form with the **correct** label attached **must** be enclosed with **every lesson** submitted for correction, as illustrated below.

Correct use of these labels will ensure prompt processing and grading of your lessons.

The enclosed **Lesson Labels** must be checked for spelling and address details.

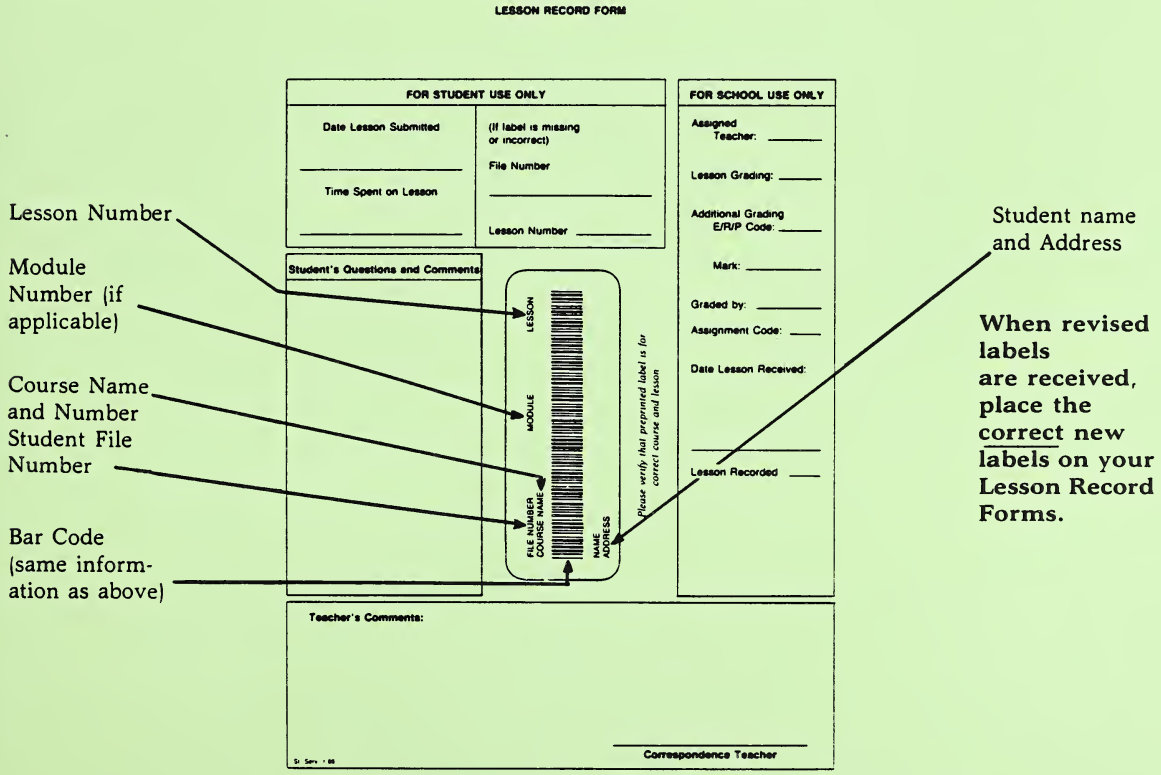
Please advise the Alberta Correspondence School promptly of any changes in name, address, school, or any other details and we will issue a revised set of labels. Your file number is permanently assigned and **must** be included on all correspondence with the Alberta Correspondence School. If the proper label and Lesson Record Form is not attached to each lesson as indicated it will delay your lessons being processed and credited to you.

Lesson labels are to be attached to the **lesson record forms** in the space provided for student name and address.

Check carefully to ensure that the **subject name, module number** and **lesson number** on each label corresponds exactly with the lesson you are submitting.

Labels are to be **peeled** off waxed backing paper and **stuck** on the lesson record form.

Only **one** label is to be placed on each lesson.



When revised labels are received, place the correct new labels on your Lesson Record Forms.

DO NOT MARK OR COVER BAR CODING.

CHANGE OF ADDRESS

If the address on your lesson record form differs from the address you supplied on your registration application, please explain. Indicate whether the different address is your home, school, temporary or permanent change of address.

LESSON RECORD FORM

3240 Chemistry 30

Revised 90/07

FOR STUDENT USE ONLY

Date Lesson Submitted

_____

Time Spent on Lesson

_____

(If label is missing or incorrect)

File Number

_____

Lesson Number _____

FOR SCHOOL USE ONLY

Assigned Teacher: _____

Lesson Grading: _____

Additional Grading E/R/P Code: _____

Mark: _____

Graded by: _____

Assignment Code: _____

Date Lesson Received:

_____

Lesson Recorded _____

Student's Questions and Comments

Apply Lesson Label Here

Name

Address

Postal Code

Please verify that preprinted label is for correct course and lesson.

Teacher's Comments:

_____

Correspondence Teacher

St. Serv. 21-89

ALBERTA CORRESPONDENCE SCHOOL

MAILING INSTRUCTIONS FOR CORRESPONDENCE LESSONS

1. BEFORE MAILING YOUR LESSONS, PLEASE SEE THAT:

(1) All pages are numbered and in order, and no paper clips or staples are used.
(2) All exercises are completed. If not, explain why.
(3) Your work has been re-read to ensure accuracy in spelling and lesson details.
(4) The Lesson Record Form is filled out and the correct lesson label is attached.
(5) This mailing sheet is placed on the lesson.

2. POSTAGE REGULATIONS

Do **not** enclose letters with lessons.

Send all letters in a separate envelope.

3. POSTAGE RATES

First Class

Take your lesson to the Post Office and have it weighed. Attach sufficient postage and a green first-class sticker to the front of the envelope, and seal the envelope. Correspondence lessons will travel faster if first-class postage is used.

Try to mail each lesson as soon as it has been completed.

When you register for correspondence courses, you are expected to send lessons for correction regularly. Avoid sending more than two or three lessons in one subject at the same time.

COMPLETE THIS QUESTIONNAIRE AND RETURN WITH LESSON ONE

Chemistry 30 Course Code 3240

Name _____ Age ☐☐ File Number ☐☐☐☐☐☐☐

Address _____ Phone Number ☐☐☐☐☐☐☐

_____ Postal Code ☐☐☐ ☐☐☐

1. Name of present school (if in attendance). _____

2. Give your final mark (if any) in the following subjects:

Science 9 ____	Chemistry 10 ____	Mathematics 10 ____	Biology 10 ____	Physics 10 ____
Mathematics 9 ____	Chemistry 20 ____	Mathematics 20 ____	Biology 20 ____	Physics 20 ____
	Chemistry 30 ____	Mathematics 30 ____	Biology 30 ____	Physics 30 ____

3. Do you plan to purchase a laboratory kit? _____

4. List any special qualifications or handicaps (jobs, illness, disabilities, etc.) which may influence your progress in this course. _____

5. What is your reason for enrolling in this course? _____

6. List any other subjects you are studying by correspondence instruction. _____

Lesson	In	Out	Grade		Lesson	In	Out	Grade
1					A			
2					B			
3					C			
4					D			
5					E			
6					F			
7					G			
8					H			
9					I			
10					J			
11								
12								
13								
14								
15								
16								
17								
18								
19								
20								
EXAM								

Lesson Grade _____ **Exam Portion** ☐

Lesson Portion ☐

Final Grade ☐

How To Obtain a Beam Balance and a Set of Weights

and a Thermometer and a Graduated Cylinder on Loan

Please be reminded that you will need this material for experiments in Chemistry 30. Since you need the material immediately you may want to work on the theory part of Lessons one and two until the material arrives.

The materials are only available on loan to students who live in the Province of Alberta and have purchased the Chemistry 30 laboratory kit from the Alberta Correspondence School. To obtain this equipment, complete the application form on the reverse side of this page and send it to the following address:

Alberta Correspondence School
Alberta Education
Box 4000
Barrhead, Alberta
TOG 2P0

After the experiments are done, immediately return the materials to the Alberta Correspondence School in the condition you received the equipment.

Students living outside of the Province of Alberta are responsible for obtaining the use of a beam balance and a set of weights and a thermometer and a graduated cylinder to complete the experiments requiring this equipment. The use of these items may be available from local schools or industries. As well the equipment can be purchased from Scientific Supply Companies such as Boreal Laboratories Ltd.

Boreal Laboratories Ltd.
1820 Mattana Avenue
Mississauga, Ontario
L4X 1K6

or

Central Scientific Company
2200 S. Sheridan Way
Mississauga, Ontario

Before you purchase anything check local outlets for these items.

APPLICATION FOR LOAN OF A BEAM BALANCE AND A SET OF WEIGHTS

AND A THERMOMETER AND A GRADUATED CYLINDER

Name: _____ File Number: _____

Address: _____

_____

Postal Code _____

I have purchased a laboratory kit for Chemistry 30 and reside in the Province of Alberta. I am ready to use the beam balance and set of weights and a thermometer and a graduated cylinder to perform the required laboratory experiments.

Please send me **on loan** the above items.

I agree to use the material carefully and to return it in good condition after the experiments are completed.

_____

(Signature in Writing)

Note: The Alberta Correspondence School will **NOT LEND** the items to a student with an address outside of the Province of Alberta and to a student who has not purchased a Chemistry 30 laboratory kit.

N.B. Work on the theory part of the first few lessons until this material arrives.

Originated by:	Date:	Authorized by:	Date:
Input by:	Date:	Verified by:	Date:

REVIEW

A. Math Review
B. Review of Chemistry 10
C. Review of Chemistry 20
D. Review - Significant Digits

Depending on your background, this lesson may go either very slowly or very quickly for you. The math is essential for doing many chemistry problems in later lessons. In reviewing Chemistry 10 and 20, we will assume that you have taken this material in previous courses, so we will just ask questions. If you have trouble with any area, we will give appropriate responses to clear up areas of difficulty. Your lesson notes from the previous two years, or the present textbook may help you with some of the problems.

A. Math Review

Before we get into Chemistry 30, you must have the necessary mathematics background to do the problems in chemistry. In this course, you must be able to multiply, divide, and find square roots of numbers with large negative exponents. In case you are a bit rusty with this, hopefully it will be cleared up in this lesson before you must apply the math to your chemistry problems. If you know your math, you may skip reading the rest of this section and do Exercise 1 right away.

When multiplying two or more exponential numbers, the exponents are added. Be careful not to add the absolute values of the numbers, but to consider the sign in front of the number. For example, note the following three additions:

$3 + 4 = 7$
$3 + (-4) = -1$
$(-3) + (-4) = -7$

When exponential numbers are multiplied, the bases are multiplied together, and the exponents are added. For example:

$$(3 \times 10^3) \times (2 \times 10^4) = (3 \times 2) \times (10^3 \times 10^4) = 6 \times 10^{3+4} = 6 \times 10^7$$

$$3 \times 10^3 \times 2 \times 10^{-4} = 6 \times 10^{3+(-4)} = 6 \times 10^{-1}$$

$$3 \times 10^{-3} \times 2 \times 10^{-4} = 6 \times 10^{-3+(-4)} = 6 \times 10^{-7}$$

When exponential numbers are divided, the bases are divided, and the exponents are subtracted. When subtracting exponents, when a negative number is subtracted, you are in effect adding the number. Just like when someone is taking a debt away from you, he is in effect giving you money. For example:

$(3) - (4) = -1$
$(3) - (-4) = 7$
$(-3) - (-4) = +1$

To apply this to division, note the following examples:

$$\frac{3 \times 10^3}{2 \times 10^4} = \frac{3}{2} \times 10^{3-4} = 1.5 \times 10^{-1}$$

$$\frac{3 \times 10^3}{2 \times 10^{-4}} = 1.5 \times 10^{3-(-4)} = 1.5 \times 10^7$$

$$\frac{3 \times 10^{-3}}{2 \times 10^{-4}} = 1.5 \times 10^{-3-(-4)} = 1.5 \times 10^1$$

When you have several exponential numbers in the numerator, and several exponential numbers in the denominator, you follow the same procedures, i.e. - you multiply all bases together, both in the numerator and in the denominator. Then these numbers are divided. Then all exponents in both parts are added together and then subtracted from each other. By doing it this way, you in effect reduce several numbers in the numerator and denominator down to one exponential number in each case. For example:

$$\frac{2 \times 10^3 \times 3 \times 10^{-4} \times 4 \times 10^5}{5 \times 10^6 \times 6 \times 10^{-1} \times 7 \times 10^2} = \frac{2 \times 3 \times 4 \times 10^3 \times 10^{-4} \times 10^5}{5 \times 6 \times 7 \times 10^6 \times 10^{-1} \times 10^2}$$

$$= \frac{24 \times 10^{3+(-4)+5}}{210 \times 10^{6+(-1)+2}} = \frac{24 \times 10^4}{210 \times 10^7}$$

Since all numbers should always be written as a number between 1 and 10, with 10 to the appropriate power,

$$\frac{24 \times 10^4}{210 \times 10^7} \text{ becomes } \frac{2.4 \times 10^5}{2.1 \times 10^9}$$

Obviously, if you make the base smaller by a factor of 10, the exponent must be larger by a factor of 10, otherwise you don't have the same number. Now:

$$\frac{2.4 \times 10^5}{2.1 \times 10^9} = \frac{2.4}{2.1} \times 10^{5-9} = 1.14 \times 10^{-4}$$

When you square a certain number, the base number is multiplied by itself, and the two exponents are multiplied together, — they are <u>not</u> squared. For example,

$$(3 \times 10^4)^2 = 3^2 \times (10^4)^2 = 9 \times 10^{4 \times 2} = 9 \times 10^8.$$

It is <u>not</u> 9×10^{16} which is a common error by students. To check that 9×10^8 is the correct answer, you could rewrite $(3 \times 10^4)^2$ as $3 \times 10^4 \times 3 \times 10^4$ and carry on as before. In this case, when exponential numbers

were multiplied, you would get $3 \times 3 \times 10^{4+4} = 9 \times 10^{8}$ which is what we had before. To find the square root of exponential numbers, you must do the opposite as when numbers were squared. For square roots, you must get the square root of the base, and divide the exponent by 2. See the examples below.

$$\sqrt[2]{9 \times 10^{6}} = \sqrt[2]{9} \times \sqrt[2]{10^{6}} = 3 \times 10^{6/2} = 3 \times 10^{3}.$$

or $$\sqrt[2]{9 \times 10^{-8}} = \sqrt[2]{9} \times \sqrt[2]{10^{-8}} = 3 \times 10^{-8/2} = 3 \times 10^{-4}.$$

Finding the square root of a number is the same as raising it to the $\frac{1}{2}$ power. For example, $\sqrt[2]{9 \times 10^{-8}}$ could be written as $(9 \times 10^{-8})^{\frac{1}{2}} = 9^{\frac{1}{2}} \times 10^{-8\left(\frac{1}{2}\right)} = 3 \times 10^{-4}$. When finding square roots, your exponent should be divisible by 2. If it isn't, you should change the base to make the exponent divisible by 2.

For example, $\sqrt[2]{9 \times 10^{9}} = 3 \times 10^{4.5}$ but the number would be much more meaningful if it were written as 10 to a whole number. In this case, $9 \times 10^{9} = 90 \times 10^{8}$.

$$\sqrt{90 \times 10^{8}} = \sqrt{90} \times \sqrt{10^{8}}$$
$$= 9.5 \times 10^{4}$$

(To get the square roots of numbers, use a calculator.) Always be sure you have whole numbers to work with. For example, to get $\sqrt{9 \times 10^{-5}}$, convert this to $\sqrt{90 \times 10^{-6}}$ rather than $\sqrt{0.90 \times 10^{-4}}$, since whole numbers are much easier to work with. In this case $\sqrt{90 \times 10^{-6}} = 9.5 \times 10^{-3}$. Should you come across cube roots or higher powers, be sure the exponent is divisible by 3, or whatever your root happens to be.

Exercise 1

In the following questions be sure your answer is a number between 1 and 10, with 10 to the appropriate power.

(1) $2 \times 10^{3} \times 5 \times 10^{-5} =$

(2) $3 \times 10^{-3} \times 4 \times 10^{-4} =$

(3) $\dfrac{5 \times 10^{-3}}{2.5 \times 10^{8}} =$

(4) $\frac{9 \times 10^{-5}}{6 \times 10^{-3}} =$

(5) $\frac{5 \times 10^{3} \times 6 \times 10^{-5} \times 2 \times 10^{1}}{3 \times 10^{4} \times 2 \times 10^{-8} \times 7 \times 10^{-2}}$

(6) $(4 \times 10^{5})^{2} =$

(7) $(2 \times 10^{4})^{3} =$

(8) $\sqrt{25 \times 10^{10}} =$

(9) $\sqrt{2.5 \times 10^{11}} =$

(10) $\sqrt{3.6 \times 10^{-7}} =$

B. Review of Chemistry 10

The proper SI unit for energy is the joule. However, since there was no Chemistry 30 book available in SI units, we will be working in kilocalories instead of joules.

1 cal (calorie) = 4.2 J (joules)
1 kcal (kilocalorie) = 4200 J

Also, the proper SI unit for the concentration of a solution is mol/m^3 rather than mol/L. Since there are 1000 L in a cubic metre, you must multiply the mol/L by 1000 to get mol/m^3. Whenever you see a capital M, it refers to moles per litre.

In SI, mol means moles
mL means millilitre
L means litre
m means metre
J means joule
g means gram
mg means milligram
kg means kilogram
s means second
min means minute
h means hour

Note: A digital number should always be followed by the abbreviated SI unit.

Exercise 2

(1) Give the equivalents for the following in the units that are indicated.

(a) 300 cal = _____ J
(b) 84 J = _____ cal
(c) 3500 cal = _____ kcal
(d) 650 J = _____ kcal
(e) 500 g = _____ kg
(f) 750 m^3 = _____ L
(g) 900 mL = _____ cm^3
(h) 490 mL = _____ L
(i) 0.03 mol/L = _____ mol/m^3
(j) 1.5 mol/L = _____ mol/m^3
(k) 50 mol/m^3 = _____ mol/L
(l) 2.5 mol/m^3 = _____ mol/L

(2) Indicate whether the following changes are physical or chemical.

(a) Molecules A and B combine to produce molecules C and D.

_____

(b) In the electrolysis of $NaCl_{(aq)}$, $Na_{(s)}$, and $Cl_{2(g)}$ are produced.

_____

(2) (c) Two colorless liquids are mixed together, and an orange liquid results. _____

(d) Oxygen gas is heated up from 50° C to 90° C. _____

(e) Sugar dissolves in water, but the conductivity of the solution is the same afterwards as before. _____

(f) Salt dissolves in water, causing the electrical conductivity of the solution to greatly increase. _____

(g) Ice melts to water. _____

(h) Water evaporates. _____

(i) Pressure is applied to two gases in a container, which causes the color to change from a red to a pink color. _____

(j) An acid and a base react to produce salt and water. _____

(k) Wood burns in air. _____

(l) Potassium permanganate is oxidized. _____

(m) Liquid oil is hydrogenated and a solid fat results. _____

(n) A large chunk of ore (Fe_2O_3) is reduced to the pure metal (Fe). _____

Answer true or false to the following questions.

(3) (a) A neutral molecule must have as many protons as neutrons. _____

(b) A positive ion is produced when electrons are lost. _____

(c) A positive ion with a charge of +3 is produced when a neutral molecule gains three protons. _____

(d) A negative ion is produced when electrons are gained. _____

(e) A homogeneous mixture is produced when salts completely dissolve in water. _____

(f) A heterogeneous mixture is produced when a salt is not capable of completely dissolving in water. _____

(g) Ionic substances, are produced when the two substances in the molecule have a great difference in electronegativity, which usually occurs when the two substances are far apart on the periodic table. _____

(h) When two nonmetals combine, a molecular substance is usually produced, which does not readily ionize in solution. _____

(i) When the chemical symbol for an element has two letters in it, the first letter is always a capital, and the second letter is a lower case letter. _____

(j) A compound must have two or more different elements in it. _____

(k) A mole of any substance has Avogadro's number, or 6.02×10^{23} particles of that substance. _____

(4) Write the formula for the following compounds.

(a) magnesium sulfate _____

(b) magnesium sulfite _____

(c) magnesium sulfide _____

(d) iron II oxide _____

(e) iron III oxide _____

(f) tin IV chloride _____

Answer true or false.

(5) (a) In a balanced chemical equation, the number of atoms are conserved. _____

(b) In a balanced chemical equation, the number of molecules are conserved. _____

(c) Mass is conserved in a balanced equation. _____

(d) Charges are conserved in a balanced equation. _____

(e) In an ionic equation, charges and atoms are conserved. _____

(f) In a net ionic equation, in which the spectator ions from the ionic equations have been removed, atoms and charges are still balanced. _____

(6) In the following reaction, only $BaSO_4$ does not completely dissociate into ions. (If necessary read through Supplementary Information pages 13-14.)

$Na_2SO_4 + BaCl_2 \longrightarrow BaSO_4 + 2NaCl$

(a) Write the ionic equation for this reaction.

_____

(b) Eliminate the spectator ions which appear on both sides, and write the net ionic equation.

_____

C. Review of Chemistry 20

Exercise 3

Answer true or false for the following statements.

(1) All chemical bonds result when a negative electron is attracted to two or more positive nuclei at the same time.

_____

(2) The element with the least tendency to attract shared electrons is in the lower left corner of the periodic table.

_____

(3) With the exception of the inert gases, the element with the greatest tendency to attract shared electrons is in the upper right hand corner.

_____

(4) With ionic bonds, electrons are considered to be transferred from one atom to another.

_____

(5) With a polar covalent bond, the electrons are shared, but one atom has a greater pull than the other.

_____

(6) In a nonpolar covalent bond, there is an equal sharing of electrons.

_____

(7) If two atoms are close together on the periodic table, they are likely to form an ionic bond.

_____

(8) Radicals are ions which act as a unit in chemical reactions, eg. SO_4^{2-}.

_____

(9) Different radicals would have different amounts of attraction for shared electrons in a compound. _____

(10) It is the force of attraction between two different molecules of a compound that determines how high or how low the melting point is. _____

(11) Water is highly polar, so it would have a great tendency to cause other highly polar and ionic substances to ionize. _____

(12) When water causes an ionic substance to dissolve, the positive portion of the molecule would be in immediate contact with the hydrogen end of the water molecule. _____

(13) When an ionic substance dissolves, the total number of positive ions must be equal to the total number of negative ions. For example, when Na_2SO_4 dissolves in water, there are as many NA^+ as there are SO_4^{-2} ions. _____

(14) If the SO_4^{-2} ion has 48 protons, it must have 50 electrons. _____

(15) When a solution is diluted, you can use the formula $C_iV_i = C_fV_f$ to calculate the final concentration. C_i is the initial concentration. V_i is the initial volume, C_f is the final concentration and V_f is the final volume. _____

(16) With an unsaturated solution, all of the solute has dissolved, and the solution could dissolve more solute. _____

(17) When a solution is saturated, it may be possible to make more solute dissolve by heating the solution. _____

(18) Pressure has a significant effect when gases are involved. _____

(19) Pressure has a significant effect when liquids or solids are involved. _____

Exercise 4

(1) You have 150 mL of a 2 mol/L solution of HCl. What is the concentration when enough water is added to make a 250 mL solution? (Page 9 (15))

(2) You have a 3.5 mol/L solution of H_2SO_4. You want to have 500 mL of 2 mol/L H_2SO_4. How much water and how much 3.5 mol/L H_2SO_4 solution do you need?

(3) Balance the following equations by inspection.

(a) $____C_4H_{10} + ____O_2 \longrightarrow ____H_2O + ____CO_2$

(b) $____N_2 + ____H_2 \longrightarrow ____NH_3$

(4) The balanced equation for magnesium reacting with oxygen to produce magnesium oxide is:

$$2Mg_{(s)} + O_{2(g)} \longrightarrow 2MgO_{(s)}$$

If 150 g of magnesium oxide are produced, how many moles of oxygen are required? (If necessary, study examples at the back of this page.)

(5) (a) When gaseous hydrogen and gaseous oxygen react to produce liquid water, 67.5 kcal are given off for each mole of liquid water that is produced. Write a complete equation which says everything that is mentioned above.

(b) Is the above reaction exothermic or endothermic? _____

(6) What is the mass of 3.01×10^{23} molecules of H_2SO_4 in grams? (Read page 40 of your textbook, if necessary.)

(7) How many moles of atoms of oxygen are there is 4 mol of $Pb(C_2H_3O_2)_2$. (Read page 39 of your textbook.)

Examples of stoichiometric problems that may be used for review purposes.

Examples involving mole ratios and mass relationships in an equation.

Acetylene burns in air and may be represented by the following balanced equation:

$$C_2H_2 + 5/2\ O_2 \rightarrow 2CO_2 + H_2O$$

(a) If 1/2 mole of C_2H_2 burns completely, calculate the number of moles of oxygen required for complete reaction:

Solution: From the balanced equation above it is evident that one mole of C_2H_2 combines with 5/2 moles of O_2.

Therefore 1/2 mole of C_2H_2 would require 1/2 as much of oxygen, or

(1/2 x 5/2) or 5/4 moles,

or by ratio and proportion:

$$\frac{5/2 \text{ moles } O_2}{1 \text{ mole } C_2H_2} = \frac{x \text{ moles } O_2}{1/2 \text{ mole } C_2H_2}$$

$$x = \frac{5/2 \times 1/2}{1} = \frac{5}{4} \text{ or } \underline{1.25 \text{ moles}}$$

(b) Given that 39g of C_2H_2 burn completely, calculate the mass of CO_2 produced.

Solution:

(i) Convert 39g of C_2H_2 into moles.

$$\frac{39g}{26g/mol} = 1.5 \text{ mol of } C_2H_2.$$

(ii) Using the balanced equation, calculate the number of moles of CO_2 produced.

From the balanced equation it is evident that 1 mol of C_2H_2 yields 2 mol of CO_2.

Therefore 1.5 mol of C_2H_2 should yield 1.5 x 2 or 3 mol of CO_2.

(iii) Finally convert 3 mol of CO_2 into g.

3 mol x 44.01 g/mol = 132.03 g

Supplementary Information

IONIC EQUATIONS

To write ionic equations we must know which compounds are soluble and which are insoluble or very slightly soluble. This information may be given in the problem on hand, or in the form of solubility tables. Once you have established these facts, you are in a position to write the ionic equation. If a compound is soluble you must show the ions that this compound will form in solution. A list of ions with their respective charges is shown in the Chemistry 30 textbook, Appendix 2 - p. 446 or in the Data Booklet p. 10. For example, NaCl, which is common table salt and highly soluble in water would produce Na^+ and Cl^- ions, or written in equation form we would show:

$$NaCl_{(s)} \rightarrow Na^+_{(aq)} + Cl^-_{(aq)}$$

"aq" means aqueous or in water.

Take another example, Na_2SO_4 which dissolves in water to form Na^+ ions and SO_4^{-2} ions. In equation form we would show:

$$Na_2SO_{4\,(s)} \rightarrow 2Na^+_{(aq)} + SO_4^{-2}{}_{(aq)}$$

It is very important to balance these in terms of atoms and charges. The sum of **positive charges must equal the sum of negative charges.** To illustrate further, take $Al_2(SO_4)_3$ dissociating in water:

$$Al_2(SO_4)_{3(s)} \rightarrow 2Al^{+3}_{(aq)} + 3SO_4^{-2}{}_{(aq)}$$

Sometimes the term "aq" is left out in our equation for simplicity sake.

Now what about the compounds that are insoluble or very poorly soluble and will not dissociate into ions readily? Such compounds are generally written in **molecular** form. Examples of some of these compounds are: $CaCO_3$, AgCl, $BaSO_4$, $Ca(OH)_2$, NH_4OH, and H_2O.

You will note from the above examples that the compounds may not be only solids but liquids as well. You must keep in mind that some liquids like H_2O have very little tendency to dissociate into respective ions and are thus written in molecular form.

With all this information at hand, we can write complete ionic equations showing reactants and products in their proper form.

Example:

(1) $Na_2SO_4 + BaCl_2 \rightarrow BaSO_4 + 2NaCl$

Given that $BaSO_4$ is only slightly soluble and does not completely dissociate into ions while the other compounds dissociate completely we can re-write the above equation as follows:

(2) $2Na^+ + SO_4^{-2} + Ba^{+2} + 2Cl^- \rightarrow BaSO_{4(s)} + 2Na^+ + 2Cl^-$

It is advisable to balance the equation first in its ordinary form (1) and then write it in ionic form (2). This makes the final balancing a great deal easier.

It is also customary to use the subscript $_{(s)}$ after the compound that does not ionize completely. The "$_{(s)}$" denotes a solid. When chemical reactions take place the insoluble product (s) formed are also called precipitates (ppt).

In your ionic equation (2) you will note that some ions took no part in the reaction. These ions are called "spectator" ions and may be deleted from a NET ionic equation. Only those ions that form a new substance (ie. solid, water, gas, etc.) are written in the NET equation.

$$Ba^{+2} + SO_4^{-2} \rightarrow BaSO_{4(s)}$$

Consider one more example where water is a product. This usually involves an acid and a base reaction.

$$HCl + NaOH \rightarrow NaCl + H_2O$$

From past experience we know that hydrochloric acid and sodium hydroxide (lye) are a very strong (highly ionic) acid and base respectively. Water on the other hand, is mainly molecular since it has very little tendency to ionize. NaCl, from previous examples, is also highly ionic. Hence the reaction in ionic form is written as follows:

$$H^+ + Cl^- + Na^+ + OH^- \rightarrow Na^+ + Cl^- + H_2O$$

or the NET reaction:

$$H^+ + OH^- \rightarrow H_2O$$

Since the Na^+ and Cl^- ions appear on both sides of the equation we can say that they really took no part in the reaction and are deleted from the NET ionic equation.

Please use this supplementary information whenever you have some doubt about ionic equations.

Note that your textbook and these lessons use the letter M to denote $\frac{\text{mol.}}{\text{L}}$.

SIGNIFICANT DIGITS

In Chemistry, your answers to calculations should be expressed in the correct number of significant digits.

D. Significant Digits

Suppose we have a measurement of 2867 mm. This measurement could be expressed as 286.7 cm or 28.67 dm or 2.867 m. These measurements contain exactly the same four digits. Only the position of the decimal point differs. The four digits 2, 8, 6 and 7 are called **SIGNIFICANT DIGITS.** We consider measurements to be **equally accurate** if they contain the same number of significant digits. Thus, the measurements listed above are equally accurate, since each has four significant digits.

Rules for Determining Significant Digits

1. Any non-zero digit is significant, since it is part of the actual measurement.

2. Zero digits may or may not be significant, depending upon their position in the number.

   (a) Any zero digits between non-zero digits ARE significant, because they are part of the actual measurement.

   (b) Zeros on the right in whole numbers ARE NOT significant (unless information to the contrary is given), since these zeros usually indicate that the measurement has been rounded.

   (c) Zero digits on the right in decimal numbers ARE significant, since they indicate the number is accurate to that number of decimal places.

   (d) Zero digits on the left in decimal numbers ARE NOT significant, since they only function as placeholders.

EXAMPLES:

Note which zeros are significant and which are not significant in the following numbers.

1 0 0 3	*These zeros are significant. (See Rule 2 (a))*
3 5 0 0	*These zeros are NOT significant. (See Rule 2 (b))*
5.4 8 7 0	*This zero is significant. (See Rule 2 (c))*
4 0 2	*This zero is significant. (See Rule 2 (a))*
0.0 0 627	*These zeros are NOT significant. (See Rule 2 (d))*

There are occasions when it is difficult to determine if the zeros are significant, or not. In the measurement 6600 m, we cannot immediately tell whether these zeros are significant.

However, one may indicate whether zeros are significant or not by writing the measurement in scientific notation. For example, the number 6600 could be written as 6.600×10^3. The zeros would be considered significant according to Rule 2 (c).

To find how many significant digits there are in any measurement, first decide if any zeros are significant or are not significant. Then, add the number of significant zeros to the number of non-zero digits.

When counting objects, such as 10 marbles, this 10 is assumed to have an infinite number of significant digits, since it is exact.

Adding or Subtracting Measured Quantities

When adding or subtracting measured quantities add or subtract everything, and then the calculated answer should be rounded to the same precision or that of the least precise of the numbers used in computation.

Example:

$$\begin{array}{rl} 38.5 \text{ mm} & \text{(least precise)} \\ 0.123 \text{ mm} & \\ 19.50 \text{ mm} & \\ \hline 58.123 \text{ mm} & \end{array}$$

The answer should be rounded to 58.1 mm

Multiplying and Dividing Measurements

When you multiply or divide measurements, your answer should not have more significant digits than any of the original measurements. If you leave your answer with more significant digits than any of the original measurements, it will appear more accurate than it really is. **IMPORTANT RULE:** **Thus, for a given problem you should determine which measurement has the least number of significant digits and then round the answer to this same number of significant digits.**

EXAMPLE 1:

Find the area of a sheet of paper which measures 23.603 cm by 15.8 cm.

Solution

Since one of the given measurements has 5 significant digits and the other has 3 significant digits, the product should contain only 3 significant digits.

ℓ (length) = 23.603 cm (5 significant digits)
w (width) = 15.8 cm (3 significant digits)

$A = \ell w$ (Area = length x width)

$= 23.603 \times 15.8$

$= 372.9274$

$= 373\ cm^2$ *square centimetres*

(rounded to the appropriate 3 significant digits)

Thus, the area of the sheet of paper is $373\ cm^2$.

It is very important that all answers have the appropriate units, such as cm^2 in this case.

Exercise 5

(1) Add or subtract the following numbers as written. Then give your answer to the proper number of decimal places and use the appropriate units.

(a) 1.5387 m
\+ 3.6 m

_____ = _____

(b) 1.5387 cm
\+ 3.6000 cm

_____ = _____

(c) 9.8397 kg
\- 6.5 g = _____ (give answer in kg)

_____

(d) 6.445 km
\- 3.1 km

_____ = _____

(2) Multiply or divide the following numbers, give the proper number of significant digits and the proper units and write the numbers in scientific notation.

(b) $6.52 \times 10^{3}\ m \times 3.5 \times 10^{4}\ m =$

(c) $1.6 \times 10^{-18}\ J \div 1.60 \times 10^{-19}\ g =$

End of Lesson 1

LESSON RECORD FORM

3240 Chemistry 30

Revised 90/07

FOR STUDENT USE ONLY

Date Lesson Submitted

_____

Time Spent on Lesson

_____

(If label is missing or incorrect)

File Number

_____

Lesson Number _____

FOR SCHOOL USE ONLY

Assigned Teacher: _____

Lesson Grading: _____

Additional Grading E/R/P Code: _____

Mark: _____

Graded by: _____

Assignment Code: _____

Date Lesson Received:

_____

Lesson Recorded _____

Student's Questions and Comments

Apply Lesson Label Here

Name

Address

Postal Code

Please verify that preprinted label is for correct course and lesson.

Teacher's Comments:

_____

Correspondence Teacher

St. Serv. 21-89

ALBERTA CORRESPONDENCE SCHOOL

MAILING INSTRUCTIONS FOR CORRESPONDENCE LESSONS

1. BEFORE MAILING YOUR LESSONS, PLEASE SEE THAT:

(1) All pages are numbered and in order, and no paper clips or staples are used.
(2) All exercises are completed. If not, explain why.
(3) Your work has been re-read to ensure accuracy in spelling and lesson details.
(4) The Lesson Record Form is filled out and the correct lesson label is attached.
(5) This mailing sheet is placed on the lesson.

2. POSTAGE REGULATIONS

Do **not** enclose letters with lessons.

Send all letters in a separate envelope.

3. POSTAGE RATES

First Class

Take your lesson to the Post Office and have it weighed. Attach sufficient postage and a green first-class sticker to the front of the envelope, and seal the envelope. Correspondence lessons will travel faster if first-class postage is used.

Try to mail each lesson as soon as it has been completed.

When you register for correspondence courses, you are expected to send lessons for correction regularly. Avoid sending more than two or three lessons in one subject at the same time.

RATES OF CHEMICAL REACTIONS

A. Introduction
B. The Nature of Chemical Reactions
C. Effect of Concentration - Collision Theory
D. Experiment 1 - A Study of Reaction Rates

A. Introduction

A candle remains in contact with air indefinitely without observable reaction while white phosphorus in a very finely divided condition bursts into flame when exposed to air. A mixture of natural gas and air in a closed room remain indefinitely without reacting but may explode violently if a glowing cigarette is brought into the room or if a light switch is turned on causing an electrical spark. All of the above are chemical reactions with oxygen from the air, but require very different amounts of time. Why then, are some chemical reactions so extremely rapid and others so agonizingly slow? To be able to answer this question we must first know what factors influence the rate of chemical reactions. Let us first illustrate what is meant by the rate of chemical reaction. Consider the reaction between carbon monoxide (CO) and nitrogen dioxide (NO_2). The equation for this reaction is:

$$CO + NO_2 \longrightarrow CO_2 + NO$$

If we heat a mixture of CO and NO_2 to 200°C, we observe a gradual disappearance of the reddish-brown color of NO_2 which is convincing enough that a reaction is taking place. We can find the rate of the process by measuring the change in color during successive measured periods of time, (ie. one minute intervals). Since the other gases are colorless, the color change is proportional to the change in the number of moles of NO_2 present in the given container, (ie. 1 L flask.) If we divide the change in the quantity of NO_2 per litre by the time interval (one minute), the quotient is the rate of the reaction.

$$\text{Rate of Reaction} = \frac{\text{change in concentration of } NO_2}{\text{time interval}}$$

We can also express the rate of reaction in terms of consumption of CO or in terms of production of either CO_2 or NO. Which we use depends upon convenience of measurement. If we prefer to measure the production of NO, we will express the rate in the form:

$$\text{Rate of Reaction} = \frac{\text{increase in concentration of NO}}{\text{time interval}}$$

The change in concentration can be expressed in any set of units which is most convenient. If a substance is a solution, moles per litre is usually used; if the substance is a gas, partial pressures are convenient. The time

interval can be in microseconds such as for the explosion of white phosphorus, minutes or hours for burning of a candle, and days or years for the rusting of an automobile. Now that we have some understanding of what is meant by the rate of chemical reactions, we can now devote some time to the study of how certain factors influence the rate of chemical reactions.

B. The Nature of Chemical Reactions

In Section 12.1, page 244, you are given two chemical reactions using the permanganate ion (MnO_4^-). Which of the two chemical reactions has a faster rate of reaction, the one with the ferrous ion (Fe^{+2}) or the one with the oxalate ion ($C_2O_4^{-2}$)? _____ What evidence do we have that a reaction had taken place? _____

In the two reactions just described, you have noted that the reacting species are ionic. $Fe^{+2}_{(aq)}$, $MnO_4^-{}_{(aq)}$ and $H^+_{(aq)}$. The symbol (aq) indicates that all ions are aquated in water solutions but to simplify equations we will often omit the symbol (aq). Since both of these reactions take place at the same temperature, and the concentration of the reacting species, MnO_4^- and H^+ are almost the same, the difference in their rates of reaction must be due to some specific characteristic of the Fe^{+2} and the $C_2O_4^{-2}$ ions.

Likewise, in the two following reactions, one with NO and the other with CO, we note a large difference in their rates of reaction. Here again the specific characteristics of NO and CO play an important role with regards to how fast or how slow the reaction occurs.

The identification of those molecular characteristics which determine rate behavior is an interesting and important frontier of chemistry. Chemical reactions which involve the breaking of several chemical bonds and the formation of new chemical bonds tend to proceed slowly at room temperature. The reaction of $C_2O_4^{-2}$ and MnO_4^- is of this type since many bonds have to be broken in the five moles of $C_2O_4^{-2}$ ions and the two moles of MnO_4^- ions to form 10 mol of CO_2 and 2 mol of Mn^{+2}, (refer to equation). This reaction proceeds slowly as might be expected. The reaction between CO and O_2 also involves breaking of bonds and forming new ones, and is slow at room temperature. In contrast, the reaction between Fe^{+2} and MnO_4^- is fast, although it also involves breaking of chemical bonds and thus we might expect it to be slow. This last example only shows that we cannot be absolutely certain of our predictions.

There are reactions which do not involve bond breaking as shown by the example below:

$$Fe^{+2} + Ce^{+4} \longrightarrow Ce^{+3} + Fe^{+3}$$

This reaction is very rapid since only a transfer of electrons between ions takes place. A prediction of this type is usually reliable. From the examples that we have observed so far, it is quite safe to state that:

(1) Reactions that do not involve bond rearrangements are usually rapid at room temperature.
(2) Reactions in which bonds are broken tend to be slow at room temperature.

To do: Read pages 243 - 244 in the textbook, including Section 12-1.

Exercise 1

(1) The rate of movement of any automobile can be expressed in the units of kilometres per hour. In what units would you express the rate at which:

(a) a family consumes eggs?

_____

(b) a propeller turns?

_____

(c) a small infant gains weight?

_____

(d) you spend money?

_____

(e) a movie film moves through a projector?

_____

(f) a plane gains altitude?

_____

(g) automobiles are produced by Ford Motor Company?

_____

(2) Pick the member of each pair having the greater reaction rate, assuming similar conditions within each pair.

(a) Evaporation of gasoline or evaporation of water.

_____

(b) Fresh apples or bananas ripening in a grocery store.

_____

(c) Iron rusting or copper corroding.

_____

(3) Observe the following reactions carefully and answer the questions that follow:

(i) $3Fe^{+2}_{(aq)} + NO_3^-{}_{(aq)} + 4H^+_{(aq)} \longrightarrow 3Fe^{+3}_{(aq)} + NO_{(g)} + 2H_2O_{(l)}$

(ii) $Cr^{+2}_{(aq)} + Fe^{+3}_{(aq)} \longrightarrow Cr^{+3}_{(aq)} + Fe^{+2}_{(aq)}$

(iii) $C_8H_{18(l)} + 12\frac{1}{2}O_{2(g)} \longrightarrow 8CO_{2(g)} + 9H_2O_{(g)}$

(iv) $PbO_{2(g)} \longrightarrow PbO_{(g)} + \frac{1}{2}O_{2(g)}$

(v) $Ba^{+2}_{(aq)} + SO_4^{-2}{}_{(aq)} \longrightarrow BaSO_{4(s)}$

(a) Which, if any, of the above reactions are likely to be very rapid at room temperature? _____ Explain. _____

_____

(b) Which, if any, are likely to be extremely slow at room temperature? _____ Explain. _____

_____

C. Effect of Concentration - Collision Theory

To do: Read Section 12-2, pages 244 - 245.

A great number of experiments, similar to the one that you will perform in Lesson 2, will show that for many reactions, raising the concentration of a reactant increases the rate of reaction, while lowering the concentration has the opposite effect. However this is not true for all reactions, since some reactions proceed at a rate independent of the concentration of the reactants and increasing the concentration of reactants has no effect. This particular case will be explained in more detail under Reaction Mechanisms. Why then does an increase in the concentration of reactants increase the rate of reaction? To answer this question we must first postulate that chemical reactions depend upon collisions between reacting particles, ie. atoms, molecules, or ions. This model of reaction rate behaviour is called the collision theory. We must also postulate that two molecules must come close together so that an effective collision may occur. Reaction at a distance seems rather unreasonable since atoms usually must be exchanged between reacting species. With these two

concepts in mind we can now see why the collision theory provides a successful framework for understanding the effect of concentration. Just as increasing the number of automobiles on our city streets leads to a higher rate of fender bending, then too, increasing the number of particles in a given volume gives more frequent collisions. The higher frequency of collisions results in a higher rate of reaction.

To illustrate this point further, let us look at another heterogeneous reaction system where the reactants are in two or more different phases such as the burning of wood in air as shown by the following equation:

$$\text{wood}_{(s)} + \text{oxygen}_{(g)} \longrightarrow \text{carbon dioxide}_{(g)} + \text{water}_{(g)} + \text{ash}_{(s)}$$

Common experience tells us that if you were to build a camp fire using logs as the starting material, it would be wiser to splinter the logs first if you wanted the fire going in a hurry. Splintering then, has the effect of increasing the area exposed to the oxygen around the wood particles. This in turn provides for a higher frequency of collision between the reacting particles due to a greater area thus increasing the rate of combustion. If the wood were reduced to fine sawdust and the sawdust were suspended in a current of air, the combustion would be explosive. You may have heard of reports where fine grain dust suspended in grain elevators was ignited accidently by an electrical spark to produce a highly explosive reaction and consequently destroying the building, or of instances where ignition of coal dust in underground mines was responsible for serious mine disasters. These examples further point out that area of contact of reacting particles does affect the rate of reaction when two phases are involved.

Exercise 2

(1) Assume that you were to build a fire in an ordinary wood stove, and that you wanted the fire to start in a hurry, list three things that you can do to accomplish this task.

(a) _____

_____

(b) _____

_____

(c) _____

_____

(2) The rate of a gaseous reaction may increase if the total pressure is increased. State three methods by which the pressure of a gaseous system might be increased.

(a) _____

(b) _____

(c) _____

(3) Consider two gases, A and B, in a container at room temperature. What effect will the following changes have on the rate of the reaction between these gases? Assume $A + B \longrightarrow C$.

(a) The pressure is doubled.

_____

(b) The number of molecules of gas A is doubled.

_____

(4) Why is granulated sugar preferable for use in iced tea rather than lump sugar?

_____

(5) For the reaction of marble, $CaCO_{3(s)}$, with an acid:

$$CaCO_{3(s)} + 2H^{+} \longrightarrow Ca^{+2} + CO_{2(g)} + H_2O_{(l)}$$

compare the rate of reaction when $CaCO_{3(s)}$ is in the form of large marble chips as contrasted with fine dust. _____

Since concentration of solution plays an important role in reaction rates, we will ask you to review Chapter 6 of your textbook and then attempt to solve problems (6) to (8) which appear below.

(6) Explain briefly what is meant by the terms:

solvent _____

_____

solute _____

_____

(7) What will be the concentration of a solution made by dissolving 80 g of NaOH in enough water to make 1.0 L of solution?

Hint: concentration = $\frac{\text{moles}}{\text{litres}}$

(8) If a solution contains 0.10 mol of solute in 500 mL of solution, what is its concentration?

D. Experiment 1 - A Study of Reaction Rates

Read the theory on pages 60 - 61 of your Laboratory Manual. Take special note of the reactions involved.

Purpose:

To determine quantitatively the influence of temperature, concentration, and a catalyst on the time required for a reaction to occur.

This experiment is found on page 60 of your Laboratory Manual. In a classroom situation, the three solutions are prepared for the students, but since it is not practical to send solutions by mail, and also since some have to be freshly prepared, we will therefore supply you with the compounds and tell you how to prepare each solution.

Materials Needed:

*2 - 250 mL graduated plastic beakers
1 thermometer (lent)
1 - 10 mL graduated cylinder (lent)
*1 - stirring rod
tap water
1 tin can (from canned vegetables or soup)
1 sweep handle watch (to record seconds)
ice (2 cubes)
*2 - 19 x 150 mm test tubes
*1 eye dropper
3 containers for solutions (clean jars or styrofoam cups will be satisfactory)

*8.3 g of KI
*2 or 3 crystals of copper sulfate
*0.20g sodium thiosulfate ($Na_2S_3O_3 \cdot 5H_2O$) for Solution B
*5.7 g ammonium peroxydisulfate ($(NH_4)_2S_2O_8$) for Solution C
*corn starch
balance (lent)

Procedure:

Part I - The Effect of Concentration

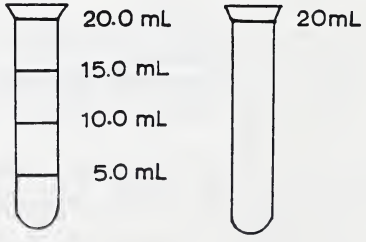
Read the theory on pages 60 and 61 of your Laboratory Manual, paying special attention to the equations of each reaction. You will note that there are seven different combinations of Solutions A, B, and C to be investigated in this part of the experiment.

Mixture 1 calls for the original solutions as they were first prepared. In Mixtures 2, 3 and 4, Solution A goes through three consecutive stages of dilution, while in Mixtures 5, 6, and 7, Solution C goes through 3 consecutive stages of dilution. Please remember that the total volume of each solution remains constant, even after dilution.

Table 28.1 of your Laboratory Manual is somewhat modified in order to accommodate the concentrations of Solutions A and C (mol/L) and also to provide for the time elapsed. Since accurate time for each reaction is necessary, it may be necessary to ask someone to help you keep time, while you are mixing the solutions together and watching for the first sign of blue to appear. The temperature of all solutions will be near room temperature if solutions were prepared a little in advance of doing the experiment.

(1) To save you time and avoid possible contamination of solutions, you may calibrate your 19 x 150 mm test tube as follows: Measure off 5.0 mL of water with your graduated cylinder and pour it into the test tube. Mark this volume by attaching a piece of tape on the test tube. Next, measure off 5.0 more mL of water; again paste another strip of tape to show a new volume of 10.0 mL. Do the same for 15.0 mL and 20 mL. Your test tube will now appear graduated as follows.

This test tube can now be used to measure off Solutions A and C in Part I. When changing from Solution A to Solution C, do not forget to rinse the test tube. Calibrate the second test tube at the 20 mL mark to measure off Solution C for Mixtures 1, 2, 3 and 4.



LAB HINTS:

a) Make 3% starch solution, measure out about 1 g of corn starch and place into a clean sauce pan or beaker. Add 30 mL of hot water and boil for about a minute. Set aside to cool.

b) To prepare Solutions A, B and C, follow the instructions below:

Solution A - To prepare a 0.20 mol/L solution, dissolve 8.3 g of potassium iodide (KI) in 250 mL of water.

Solution B - To prepare a 0.0050 mol/L solution, dissolve 0.20 g of sodium thiosulfate ($Na_2S_2O_3 \cdot 5H_2O$) in 160 mL of water. Then add 3 mL of the 3% starch solution that you prepared previously, but not far in advance of when you are to do the experiment.

Solution C - To prepare a 0.10 mol/L solution, dissolve 5.7 g of ammonium peroxydisulfate ($(NH_4)_2S_2O_8$) in 250 mL of water.

c) For part III of your experiment you will need a catalyst, 0.01 mol/L solution of copper sulfate. Dissolve about two or three crystals of copper sulfate ($CuSO_4 \cdot 5H_2O$) in 10 mL of water, and keep it handy for part III.

d) For parts II and III of your experiment, you will need a container large enough to warm or cool your solution to the desired temperature by placing the test tubes and the graduated cylinder with their respective solutions in a water bath.

(2) Using your calibrated test tube, measure out 20 mL of Solution A. Using the second 20 mL test tube, measure out an equal volume (20 mL) of Solution C.

(3) Using your graduated cylinder, measure out 10 mL of Solution B containing the starch, and pour into a 250 mL clean beaker.

(4) Having all three solutions ready, you are now ready for the mixing operation and for the observing of the time for the reaction. Your helper should be prepared to give you a signal when to pour the solutions together and to record the time at which the solutions were mixed. Upon receiving a signal, pour both Solutions A and C quickly and simultaneously into the beaker containing Solution B. Stir with a stirring rod to mix the solutions thoroughly. As soon as the first sign of blue appears, signal your timekeeper and he will give you the time that it took for the reaction to occur. Record the time in seconds in the Table - I under "Elapsed Time".

You will not have enough solution to repeat every mixture but should something go drastically wrong with any one operation, then repeat the procedure and record the correct time.

(5) After completing Mixture 1, discard the resulting blue solution from the beaker, and rinse it thoroughly. Now you are in a position to proceed with Mixture 2. Remember that in Mixture 2, Solution A is diluted, (15.0 mL of Solution A and 5.0 mL of water). Use your calibrated test tube to measure the proper volume. Use the second test tube calibrated at 20 mL to measure off Solution C. Repeat the procedures as outlined above, keeping in mind that A is diluted and B and C are as before. Continue with all the remaining required mixtures as you fill in Table I. Note that in Mixtures 5, 6 and 7, Solution A is not diluted, but Solution C is, hence you may interchange your 20 mL test tubes now to get the proper volumes of each. (Rinse before using).

Summary of Results for Part I

Complete the table on the next page by filling in the elapsed time for each mixture and also fill in the blanks by calculating the concentrations of the I^- and $S_2O_8^{-2}$ ions.

Note

*The concentrations you are to fill in in the table are the concentrations after all three solutions are combined to form mixtures but before reaction occurs. After mixing, the total volume increases to 50 mL, hence the concentration of KI or I^- is 2.5 times less than before mixing, or $0.20 \times \frac{1}{2.5} = 0.08$. After diluting Solution A in Mixture 2, the concentration of Solution A is only $\frac{15}{20}$ or $\frac{3}{4}$ of what it was in Mixture 1. Try to work out the concentrations for Solution A in Mixtures 3 and 4 and for Solution C in Mixtures 6 and 7 along the same principles.

Table - I

Mixture	Volume of Solution A (source of I^-) 0.20 M KI (mL)	*Initial Concentration mol/L of I^-	Volume of Solution B (source of $S_2O_3^{-2}$) (mL)	Volume of Solution C 0.10 M$(NH_4)_2S_2O_8$ (source of $S_2O_8^{-2}$) (mL)	Initial Concentration mol/L of $S_2O_8^{-2}$	Elapsed Time (s)
1	20.0	8.0×10^{-2}	10.0	20.0	4.0×10^{-2}	_____
2	15.0 + 5.0 water	6.0×10^{-2}	10.0	20.0	4.0×10^{-2}	_____
3	10.0 + 10.0 water	_____	10.0	20.0	4.0×10^{-2}	_____
4	5.0 + 15.0 water	_____	10.0	20.0	4.0×10^{-2}	_____
5	20.0	8.0×10^{-2}	10.0	15.0 + 5.0 water	3.0×10^{-2}	_____
6	20.0	8.0×10^{-2}	10.0	10.0 + 10.0 water	_____	_____
7	20.0	8.0×10^{-2}	10.0	5.0 + 15.0 water	_____	_____

Part II - The Effect of Temperature

In this part you will mix the three solutions, but have the reaction take place using different temperatures. Three different temperatures will be sufficient. Notice that all mixtures have the same volume of each solution. The temperature ranges that you should use, appear in the Table II below. To warm the three solutions above room temperature, use a hot water bath. Place the hot water in the tin can and immerse the test tubes and the 10 mL graduated cylinder containing the solutions into the can, being careful that no water gets into the solutions. Use a thermometer to obtain the reading of one solution. We can safely assume that the other solutions will be at the same temperature. To cool your solution below room temperature, prepare a water-ice bath into which your solution can be immersed. Record the desired temperature of one of your solutions as before and record in Table II. The The reaction time for room temperature can be taken from Mixture 1 in Part I. Again, be careful not to get any water into your solutions while immersing them into the baths. Proceed with mixing as outlined in Part I, #4, and complete the Table below.

Table II

Mixture	Solution A (source of I^-)	Solution B source of $S_2O_3^{-2}$	Solution C source of $S_2O_8^{-2}$	Temperature Range	Actual Temperature of solutions	Elapsed Time (s)
8	20.0 mL	10.0 mL	20.0 mL	0 - 15		
9	20.0	10.0	20.0	Room Temp		
10	20.0	10.0	20.0	35 - 52		

Part III - The Effect of a Catalyst

Repeat the Experiment as in Part II with the different temperature ranges, but this time add 4 drops of 0.01 mol/L copper sulfate solution, (catalyst), to Solution B. Record the elapsed time in the table below.

Table III

Mixture	Solution A (source of I^-)	Solution B source of $S_2O_3^{-2}$	Solution C source of $S_2O_8^{-2}$	Temperature Range	Actual Temperature of solutions	Elapsed Time (s)
11	20.0 mL	10.0 mL	20.0 mL	0 - 15		
12	20.0	10.0	20.0	Room Temp		
13	20.0	10.0	20.0	35 - 52		

Exercise 3: Processing the Data

(1) Of the two equations given on page 60 of your Laboratory Manual, which one would you consider in the rate determining step? _____

Why? _____

_____

(2) Which element reacts with the starch to give the characteristic blue color? _____

(3) If you added 20 mL of water to 30 mL of a 0.20 M solution of KI (Solution A) what would be the resulting concentration of I^- ions?

_____

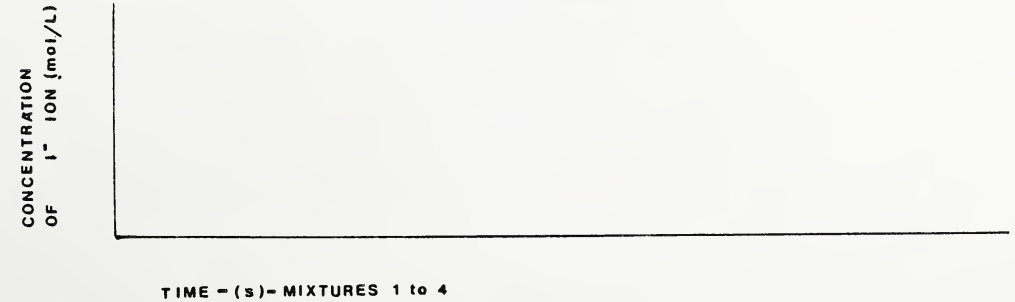
(4) In each of the mixtures, you used 10.0 mL of Solution B, (0.0050 M $Na_2S_2O_3$). Calculate, using the equation below, how many
(a) moles of I_2 will react with this much of thiosulfate ion, ($S_2O_3^{-2}$).

$$I_2 + 2S_2O_3^{-2} \longrightarrow 2I^- + S_4O_6^{-2}$$

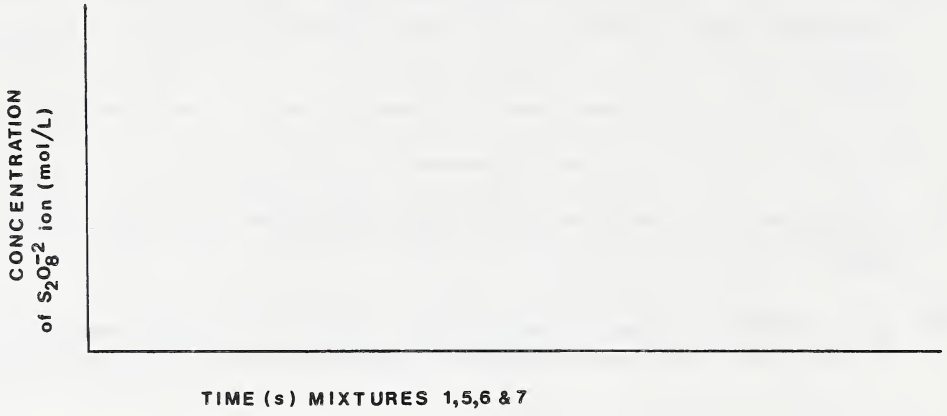
(b) How many grams of I_2 is this?

The elapsed time for each reaction is a measure of the time it takes to use up this much of $S_2O_3^{-2}$ to produce n moles of I_2. Once all the $S_2O_3^{-2}$ ions are used up, the iodine produced can no longer react and thus the solution turns blue.

(5) Make a graph by plotting initial concentration, mol/L, of iodide ions (Solution A) vs. elapsed time for Mixtures 1 to 4. Co-ordinates are given below.



(6) Make another graph, plotting concentration, mol/L of peroxydisulfate ion (Solution C), vs. elapsed time for Mixtures 1, 5, 6, and 7.



(7) How does changing the concentration of reactants affect the elapsed time for the reaction? _____

_____

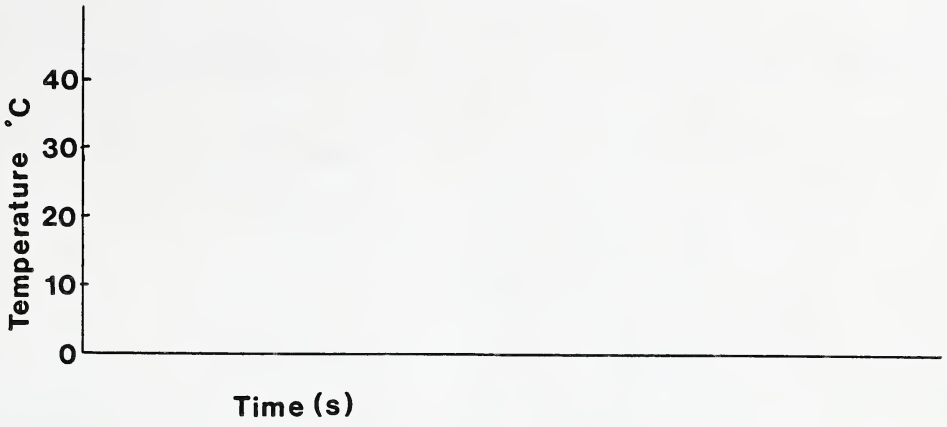
(8) We are primarily interested in the reaction between the iodide ion, I^-, and the peroxydisulfate ion, $S_2O_8^{-2}$, as represented by the following equation:

$$2I^- + S_2O_8^{-2} \longrightarrow I_2 + 2SO_4^{-2}$$

Calculate how many moles of $S_2O_8^{-2}$ are not used if all the I^- ions in Mixture 3 are completely changed to I_2 ?

Hint: In mixture three, 10 mL (0.010 L) of solution A contained (0.010 L) (0.20 mol/L) = 0.002 mol of I^- ions. Now determine the number of moles of $S_2O_8^{2-}$ required to react with this amount. Then determine how many moles would be left after the reaction.

(9) (a) Make a graph plotting temperature of the mixture vs. elapsed time for Mixtures 8, 9 and 10. Label this curve "uncatalyzed." (Table II)



(b) What can you deduce from the shape of your graph?

_____

_____

_____

(10) On the above graph, plot the temperature of the mixture vs. elapsed time for Mixtures 11, 12 and 13, (using a catalyst). Label the curve "catalyzed." (Table III)

(11) What generalizations can you deduce from a comparison of the two curves?

_____

_____

End of Lesson 2

LESSON RECORD FORM

3240 Chemistry 30

Revised 90/07

FOR STUDENT USE ONLY

Date Lesson Submitted

_____

Time Spent on Lesson

_____

(If label is missing or incorrect)

File Number

_____

Lesson Number _____

FOR SCHOOL USE ONLY

Assigned Teacher: _____

Lesson Grading: _____

Additional Grading E/R/P Code: _____

Mark: _____

Graded by: _____

Assignment Code: _____

Date Lesson Received:

_____

Lesson Recorded _____

Student's Questions and Comments

Apply Lesson Label Here

Name

Address

Postal Code

Please verify that preprinted label is for correct course and lesson.

Teacher's Comments:

_____

Correspondence Teacher

St. Serv. 21-89

ALBERTA CORRESPONDENCE SCHOOL

MAILING INSTRUCTIONS FOR CORRESPONDENCE LESSONS

1. BEFORE MAILING YOUR LESSONS, PLEASE SEE THAT:

(1) All pages are numbered and in order, and no paper clips or staples are used.
(2) All exercises are completed. If not, explain why.
(3) Your work has been re-read to ensure accuracy in spelling and lesson details.
(4) The Lesson Record Form is filled out and the correct lesson label is attached.
(5) This mailing sheet is placed on the lesson.

2. POSTAGE REGULATIONS

Do **not** enclose letters with lessons.

Send all letters in a separate envelope.

3. POSTAGE RATES

First Class

Take your lesson to the Post Office and have it weighed. Attach sufficient postage and a green first-class sticker to the front of the envelope, and seal the envelope. Correspondence lessons will travel faster if first-class postage is used.

Try to mail each lesson as soon as it has been completed.

When you register for correspondence courses, you are expected to send lessons for correction regularly. Avoid sending more than two or three lessons in one subject at the same time.

RATES OF CHEMICAL REACTIONS (continued)

E. Effect of Temperature — Collision Theory
F. Reaction Mechanisms
G. The Role of Energy in Reaction Rates
   (1) Activation Energy
   (2) Heat of Reaction
   (3) Action of Catalysts and Some Reaction Mechanisms

E. Effect of Temperature — Collision Theory

To do: Read Section 12.3

In your Experiment 1, you discovered that temperature had a marked effect upon the rate of chemical reactions. Upon raising the temperature of your solutions the reaction between iodide ions (I^-) and peroxydisulfate ions ($S_2O_8^{-2}$) was progressively faster. The same effect is observed in the reaction of a candle and air: a "lighted" match raises the temperature of the wick, which is sufficient to keep it burning and thus keep the reaction going at a reasonable rate. Why then does an increase in temperature have such a pronounced effect upon the rate of a chemical reaction?

From your reading of Section 12.3, you probably discovered that just ordinary collisions between reacting particles, no matter how frequent, will not cause chemical reactions. The collisions, to be effective, must have a combination of both, high velocity and proper geometry. To illustrate this point further, let us return to our analogy of cars bumping each other on a busy street. In a line of heavy traffic, one may receive gentle bumps from the car in front or the car behind with no visible damage done to the cars, except maybe a few cases of temper-tantrum, but on the other hand, a high speed collision may occur with enough energy to cause the collapse of a fender or a dented bumper. Here, geometry of the collision plays an important part; a low velocity bumper to bumper collision is less effective than a bumper to fender collision. Just as high-energy collisions at the proper site cause automobile damage, high-energy molecular collisions occurring at proper angles and at certain "vulnerable" spots of the reacting molecules will cause chemical reactions. This type of reasoning is further justified. Recall that for chemical reactions to occur, there must be a breakage in molecular bonds (bond damage) accompanied by rearrangement and formation of new bonds. Just as a certain minimum amount of energy is needed to bend a fender or break loose a car bumper, then too, a certain minimum amount of energy is required to cause a chemical reaction. This minimum amount of energy is commonly referred to as the "threshold energy". As the temperature increases, the distribution of molecules with higher kinetic energy also increases as shown in Figure 12.2. Collisions now involve energy greater than the threshold energy. Therefore the rate is much faster at higher temperatures.

Exercise 1

(1) Compare the number of collisions at T_1 with the number at T_2. (See Figure 12.2) _____

_____

(2) Where do more molecules have a higher kinetic energy, at T_1 or at T_2?

_____

(3) Why does a spark from a flint light your cigarette lighter?

_____

_____

(4) Consider two gases, A and B, in a container at room temperature. What effect will decreasing the temperature at constant volume have on the rate of reaction between these gases? _____

_____

(5) In an important industrial process producing ammonia (the Haber process), the overall reaction is:

$$N_{2(g)} + 3H_{2(g)} \longrightarrow 2NH_{3(g)} + 22\ 000 \text{ cal.}$$

A yield of approximately 98% can be obtained at 200°C and 1000 atm of pressure. The process makes use of a catalyst such as finely divided K_2O and Al_2O_3.

(a) Suggest a reason for the fact that this reaction is generally carried out at a temperature of 500°C and 350 atm in spite of the fact that the yield under these conditions is only about 30%.

_____

_____

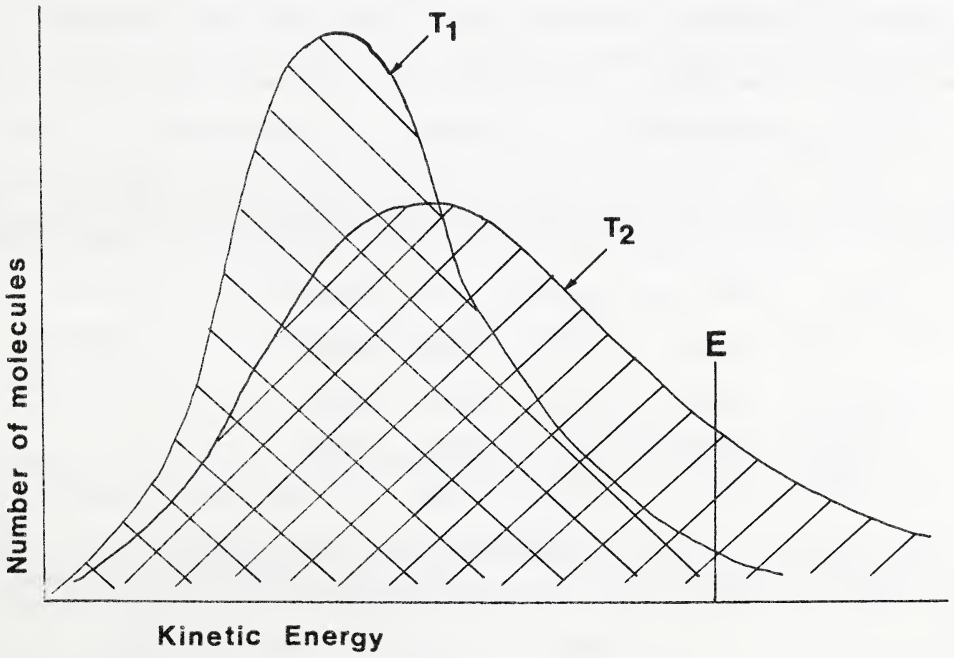
(b) Is the reaction exothermic or endothermic? _____

(c) How many grams of nitrogen must react to produce 59.5 g of ammonia?

(d) What is the heat of reaction per mole of ammonia?

(6) An increase in temperature of 10°C rarely doubles the kinetic energy of particles, and hence the number of collisions is not doubled. Yet, this temperature increase may be enough to double the rate of a slow reaction. With the aid of the diagram below explain how this can happen.

(T_2 represents the higher temperature, consider the number of molecules with energy E at these two temperatures.)



(Area under curves represents number of molecules)

F. Reaction Mechanisms

To do: Read Section 12.4, pages 246 - 248.

The example in your textbook brings out the fact that the reaction between Fe^{+2} and MnO_4^- involving a simultaneous collision of fourteen ions is highly improbable, just as a simultaneous collision of ten automobiles on a freeway would be improbable. However, experimental evidence shows that the reaction between Fe^{+2} and MnO_4^- ions does occur at an easily measurable rate, therefore the reaction must proceed by some sequence of steps rather than by a single step involving the simultaneous collision of fourteen ions. From this, we can conclude that a complex chemical reaction which proceeds at a measurable rate, must take place in a series of simpler steps. Chemists call such a series of steps the reaction mechanism.

Study the example showing the reaction between peroxydisulfate ion and iodide ions, and note how the original equation is broken down into two simpler equations. Also note why doubling the concentration of either ion has the same effect on the reaction rate. Consider another example: the oxidation of gaseous hydrogen bromide (HBr) that is reasonably rapid at high temperature.

$$4HBr_{(g)} + O_{2(g)} \longrightarrow 2H_2O_{(g)} + 2Br_{2(g)}$$

By observing the above reaction, you will note that four molecules of HBr are required for every molecule of oxygen, yet experimental evidence shows that a change in the $HBr_{(g)}$ concentration has the same effect as an equal change in the $O_{2(g)}$ concentration. To explain this phenomena, we must consider in detail the process by which HBr and O_2 react. Since there is very little chance that even five molecules will collide simultaneously, the above reaction must occur in a series of simple reactions, as shown below.

$$HBr + O_2 \longrightarrow HOOBr \quad \text{(slow)}$$

$$HOOBr + HBr \longrightarrow HOBr + HOBr \quad \text{(fast)}$$

$$HOBr + HBr \longrightarrow H_2O + Br_2 \quad \text{(fast)}$$

$$\underline{HOBr + HBr \longrightarrow H_2O + Br_2 \quad \text{(fast)}}$$

$$4HBr + O_2 \longrightarrow 2H_2O + 2Br_2$$

For any proposed reaction mechanism, we must always be able to add up all the separate steps to give the balanced equation for the observed reaction.

From the above example we also observe that each reaction requires the collision of only <u>two</u> molecules. We can see that the first step holds back the succeeding steps or reaction; in other words, it forms the "bottleneck" in the reaction between HBr and O_2. The slowest reaction ("bottleneck") in a mechanism is called the <u>rate-determining step</u>. As an analogy, consider the following situation:

> A person drives to the grocery store, parks his car in the parking lot, fills his cart with groceries, stands in a long line at the checkout counter, pays the cashier for his groceries, has the groceries bagged, and finally he drives off home. Under less than perfect conditions, any of these steps can become the rate-determining step of buying groceries. From the list above, which would you say is the rate-determining step? (Considering all other factors nearly ideal.)

Under what condition would parking your car become a rate-determining step?

To do: Exercise 12.3, page 248. Check your answers with the textbook. If you have any questions or opinions, please state them below.

<u>Exercise 2</u>

(1) Do you think the equation $C_2H_{4(g)} + 3O_{2(g)} \longrightarrow 2CO_{2(g)} + 2H_2O_{(g)}$ represents the mechanism by which ethylene, C_2H_4 burns? Why? (Read page 4)

---

(2) Hydrogen perioxide reacts with a hydrogen ion and an iodide ion according to this equation:

$$H^+ + I^- + H_2O_2 \longrightarrow H_2O + HOI$$

The mechanism often suggested by this reaction is:

$$H^+ + H_2O_2 \longrightarrow H_3O_2^+ \quad \text{(fast)}$$
$$H_3O_2^+ + I^- \longrightarrow H_2O + HOI \quad \text{(slow)}$$

(2) (a) Show that the addition of these two equations gives the overall equation. (Show addition)

(b) How would you expect the rate to be affected if the I^- concentration were doubled? _____

(c) How would you expect the rate to be affected if the H^+ concentration were doubled? _____

(d) Which of the two equations is the rate-determining step?

_____

(3) A group of students were preparing a ten-page directory. The pages have been printed and are stacked in ten piles, page by page. The pages must be (i) assembled in order, (ii) straightened and (iii) stapled in sets. If three students work together, each performing a different operation,

(a) which might be the rate-determining step?

_____

(b) What would be the effect on the overall rate if the first step were changed by ten helpers joining the person assembling the sheets?

_____

(c) What if these ten helpers joined the student working on the second step? _____

(d) The third step? _____

G. The Role of Energy in Reaction Rates

(1) Activation Energy

To do: Read Section 12.5, pages 249 - 250, and study Figures 12-6 to 12-10.

Suppose you were competing in a high jumping event and your goal was to out-perform your competition. To achieve this goal you must take a running start and then raise your body to an altitude a minimum number of metres, go over the cross bar and drop into the sandpit. Getting over the bar, without knocking it down is the

main objective. If the bar is high, you have to increase your distance from the ground, thus increasing your potential energy. If the bar is high, few individuals will get over it. On the other hand, if the bar is low, almost everyone will achieve success. It is the position of the bar that defines the barrier. If you go over it, the remainder of the process, falling into the sandpit, is sure to follow.

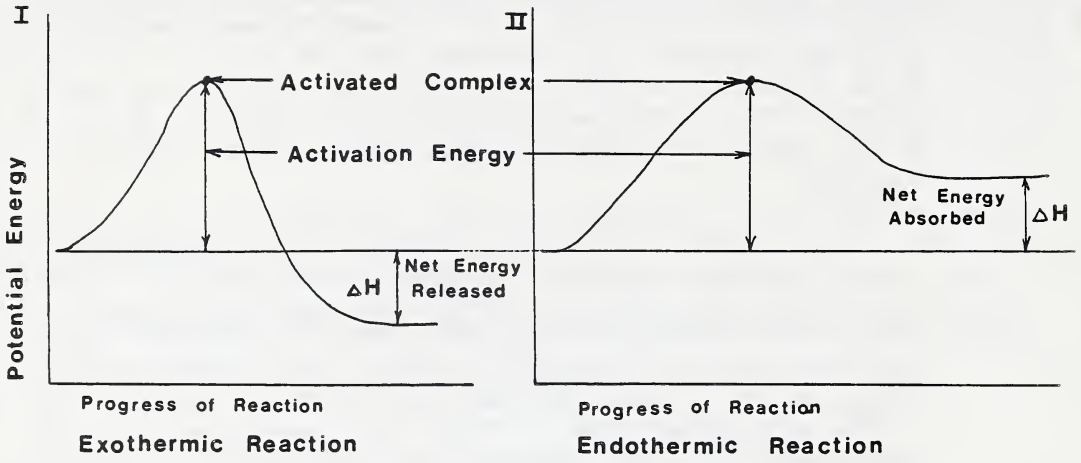
The example above can be analogous to a chemical reaction. Before reacting molecules can achieve their goal (ie. forming new compounds) molecules must first collide and atoms must momentarily take up new bonding arrangements that are less stable than in either the reactants or the products. Atoms must separate and the potential energy of the reacting particles must increase, just as in the case of the high jumper when her body separates from the ground. These high-energy molecular arrangements are like the cross bars which act as barriers which must be crossed if reaction is to be achieved. Only if the colliding molecules have sufficient energy to overcome these barriers imposed by unstable arrangements, can reaction take place. The barrier, though invisible, determines the "threshold energy", E, or the minimum energy necessary for the reaction to occur. Chemists have given E the name Activation energy.

As the potential energy increases, a level is reached where the reacting particles will undergo a transitory state, where bonds will reform to produce new products. This particular level of achievement or the "high point" of a series of events is called the activated complex. Figures 12-6 to 12-10 of your textbook illustrates a complete chain of events when two hydrogen iodide molecules react to give hydrogen and iodine. Note the activated complex in Figure 12-8.

(2) Heat of Reaction

To do: Read Section 12-6

Reactions, as you may recall, fall into two main categories - exothermic and endothermic. If the potential energy or the heat content of the products is less than the potential energy or heat content of the reactants, then energy is released, and the reaction is called exothermic. If the potential energy of the products is more than that of the reactants, then energy is absorbed and the reaction is called endothermic. In general terms, these two types of reactions can be represented graphically as shown below.

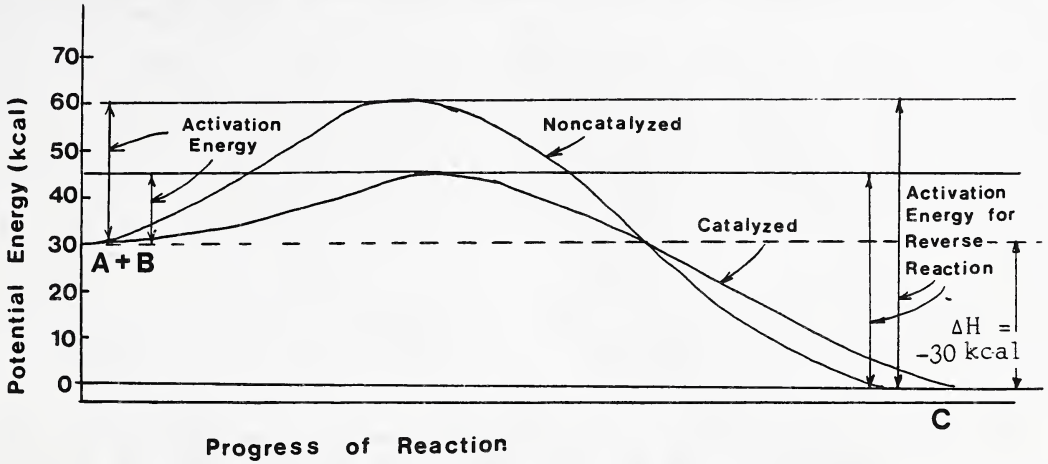


(3) Action of Catalysts and Some Reaction Mechanisms

To do: Read Section 12-7, pages 250 to 254, and Section 12-8, pages 254 to 258.

Catalysts are agents which speed up chemical reactions. Experimental evidence shows that they themselves do not take part in the reaction because the amount of catalyst before and after reaction remains the same. Upon closer observation, you will note that at first a catalyst is consumed in order to initiate new mechanisms or pathways which enable the reaction to proceed at a much faster rate, but after reaction is complete, the catalyst regenerates, therefore it appears as though it played no part in the reaction process. What catalysts do, is lower the activation energy. The action of a catalyst can be explained in terms of our mountain pass analogy. A tourist, while travelling through the Rockies, encounters a formidable mountain pass, 1700 m above sea level, obstructing travel to his next destination. He would like to take this shorter direct route, but reckons that his automobile is not up to this much of a climb. He opts for an alternate route, which is somewhat longer, but is only 310 m at the highest pass. His automobile encounters no difficulty and the net result is a successful journey to his intended destination. As in our mountain pass analogy, where an alternate route was provided to overcome a barrier, it is also true for chemical reactions, where a catalyst is added to provide a new reaction path with a different activation energy barrier. This new reaction path corresponds to a new reaction mechanism that permits the reaction to proceed via a different activated complex. More particles can get over the new, lower energy barrier and hence the rate of the reaction is increased.

The diagram below shows the analogous situation for a catalyzed and a noncatalyzed reaction: A + B ⟶ C



Exercise 3

Problems 1 to 6 relate to the potential energy diagram shown above.

(1) In the reaction A + B ⟶ C, which has a higher heat content, the reactants or the products? _____

(2) In the reaction C ⟶ A + B, which has a higher heat content, the reactants or the products? _____

(3) Is the reaction A + B ⟶ C exothermic or endothermic? _____

(4) Rewrite the forward reactions showing the net energy (ΔH) in kilocalories.

_____

(5) When a catalyst is added, does the activation energy for the forward reaction and the activation energy for the reverse reaction decrease by the same amount?

_____

(6) What does this prove about the action of a catalyst regarding forward and reverse reactions?

_____

(7) Sketch a potential energy diagram which might represent an endothermic reaction. Label parts of the curve representing activation energy, activated complex, net energy absorbed (ΔH) and your co-ordinates.

(8) (a) In Figure 12-7, why is kinetic energy decreasing as two HI molecules go up the left side of the barrier, and why is kinetic energy increasing as H_2 and I_2 go down the right side? Explain in terms of conservation of energy and also in terms of what is occuring to the various particles in relation to each other.

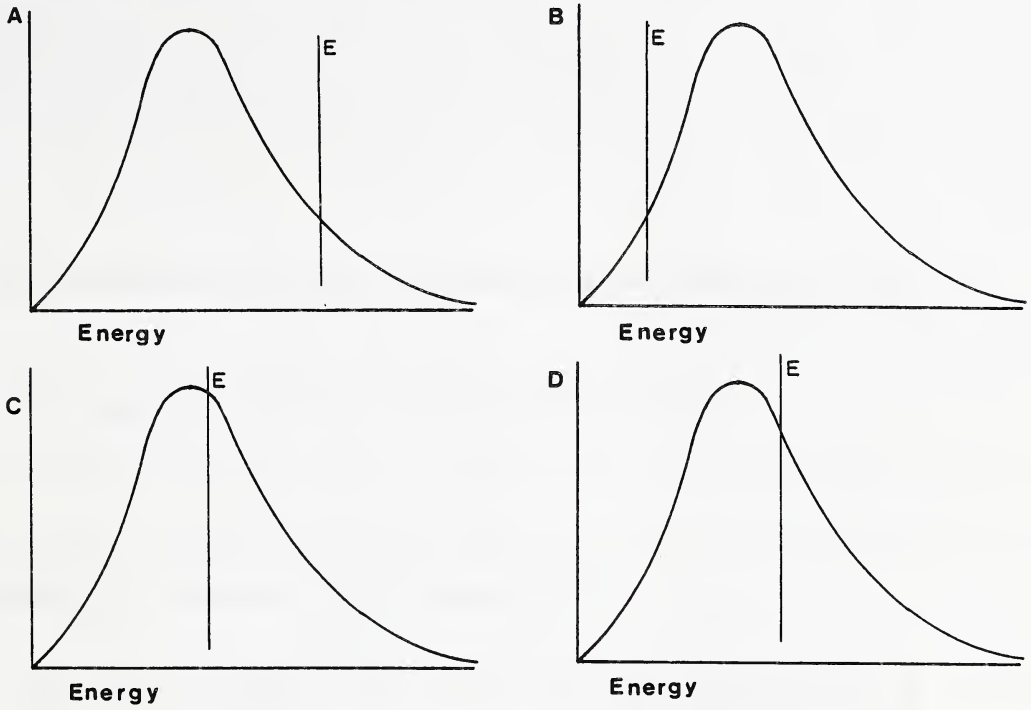
_____

_____

_____

(b) In the reaction between two HI molecules, what new molecule is formed at the activated complex? _____

Consider the following: Identical kinetic energy distribution curves for four different groups of molecules (at the same temperature and pressure) but with each group of molecules having a different threshold energy (E) before they will react.



(9) (a) Which diagram represents the fastest reaction? _____

(b) Which diagram represents the slowest reaction? _____

(10) For the reaction: $CO + NO_2 \longrightarrow CO_2 + NO$, the activation energy for the forward reaction is known to be 32 kcal/mol.

(a) According to the reaction above, when 14.0 g of CO react with NO_2, 27 kcal of heat are released. Calculate the molar heat of reaction for the reaction above.

(10) (b) Using the forward activation energy and the value you obtained in (a), calculate the activation energy for the reverse reaction.

(c) Draw a potential energy diagram for this system, indicating all three values.

(11) (a) In biochemistry, name the catalyst that is used in aiding the digestions of proteins. _____

(b) The above catalyst works on the _____ in the protein chain.

(c) After reaction is complete, does the catalyst revert to its original molecular structure? _____

(12) What is meant by molecular inversion? _____

_____

(13) In the chain reaction between H_2 and Cl_2 molecules, what is the function of light? (Study example on p. 256 of your textbook.)

_____

_____

(14) Carbon monoxide can be produced by the catalytic action of H^+ ions on formic acid, HCOOH. Show the reaction mechanism for this reaction.

(15) List 3 solid metals that are commonly used as catalysts.

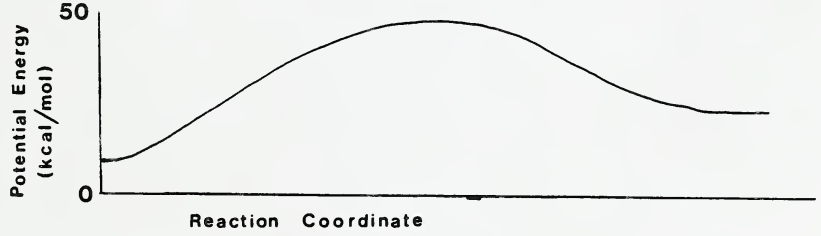
_____

(16) List one important function of the following enzymes.

(a) pepsin _____

(b) ptyalin _____

Consider the potential energy diagram below.



(17) (a) Is this reaction exothermic or endothermic? _____

(b) Would you expect this reaction to occur rapidly at room temperature? Explain. _____

_____

(c) Of the following reactions, which one might this diagram represent? (Refer to page 273 of your textbook.)

(i) $NaOH_{(s)} \rightarrow Na^+_{(aq)} + OH^-_{(aq)}$

(ii) $CH_{4(g)} + 2O_{2(g)} \rightarrow CO_{2(g)} + 2H_2O_{(g)}$

(iii) $C_{(graphite)} \rightarrow C_{(diamond)}$, (under high temperature and pressure).

_____

(18) Phosphorus, P_4, exposed to air, burns spontaneously to give P_4O_{10}. The heat for this exothermic reaction is 712 kcal/mol P_4.

(a) Draw an energy diagram for the net reaction explaining the various parts of the curve.

(b) How much heat is produced when 170.5 g of phosphorus burns?

To do: Read Section 12-9.

End of Lesson 3

LESSON RECORD FORM

3240 Chemistry 30

Revised 90/07

FOR STUDENT USE ONLY

Date Lesson Submitted

_____

Time Spent on Lesson

_____

(If label is missing or incorrect)

File Number

_____

Lesson Number _____

FOR SCHOOL USE ONLY

Assigned Teacher: _____

Lesson Grading: _____

Additional Grading E/R/P Code: _____

Mark: _____

Graded by: _____

Assignment Code: _____

Date Lesson Received:

_____

Lesson Recorded _____

Student's Questions and Comments

Apply Lesson Label Here

Name

Address

Postal Code

Please verify that preprinted label is for correct course and lesson.

Teacher's Comments:

_____

Correspondence Teacher

St. Serv. 21-89

ALBERTA CORRESPONDENCE SCHOOL

MAILING INSTRUCTIONS FOR CORRESPONDENCE LESSONS

1. BEFORE MAILING YOUR LESSONS, PLEASE SEE THAT:

(1) All pages are numbered and in order, and no paper clips or staples are used.
(2) All exercises are completed. If not, explain why.
(3) Your work has been re-read to ensure accuracy in spelling and lesson details.
(4) The Lesson Record Form is filled out and the correct lesson label is attached.
(5) This mailing sheet is placed on the lesson.

2. POSTAGE REGULATIONS

Do **not** enclose letters with lessons.

Send all letters in a separate envelope.

3. POSTAGE RATES

First Class

Take your lesson to the Post Office and have it weighed. Attach sufficient postage and a green first-class sticker to the front of the envelope, and seal the envelope. Correspondence lessons will travel faster if first-class postage is used.

Try to mail each lesson as soon as it has been completed.

When you register for correspondence courses, you are expected to send lessons for correction regularly. Avoid sending more than two or three lessons in one subject at the same time.

ENERGY CHANGES

A. Introduction
B. Energy in Phase Changes
C. Energy in Chemical Reactions

A. Introduction

To do: Read Section 5-1, pages 85-86.

Energy is difficult to define because it occurs in many forms. We have light energy, heat energy, solar energy, electrical energy, mechanical energy, and many others. One form of energy can change into another form which we call transformation of energy. For example, electrical energy can be changed into light and heat energy, solar energy can be changed into chemical energy as in solar batteries, mechanical energy of a steam-driven turbine can be changed into electrical energy by use of generators and there are many other possible transformations of energy. Energy can be generally defined as a quality associated with all matter which can be converted into work under proper conditions. However, in the lessons that follow, we will limit our study mainly to energy associated with phase changes, chemical and nuclear reactions. We will try to answer some of the following questions: Why do some reactions release energy; why do others absorb energy? How is energy stored in molecules? What is the source of this energy? How can this energy be measured? How can this energy be made available and released when needed? We will also show how a chemist can make use of this knowledge in a practical situation.

From your previous chemistry courses you probably recall that all energy associated with matter was listed under two main areas - (i) kinetic energy and (ii) potential energy. Kinetic energy was defined as energy of motion. An automobile travelling at 120 km/h or a huge snow avalanche cascading down a mountain side are some examples of kinetic energy. Potential energy on the other hand, is defined as energy of position or stored energy. A huge boulder resting on the top of a cliff several hundred metres above ground level, or a stick of dynamite locked in a storage room are some examples of potential energy. You can readily see how potential energy can change to kinetic energy.

Before we go into more details regarding energy changes it might be worthwhile to bring to your attention the fact that the unit of heat energy, the kilocalorie, which is used throughout your textbook may not be consistent with other textbooks which have adopted the joule as the unit of heat energy commonly used in the SI system of measurement. In most of our calculations we will adhere to your textbook and use calories or kilocalories. It is a simple matter to convert calories to joules if you keep in mind that one calorie is approximately 4.19 J. Note that this is the opposite of

what it says in the textbook at the bottom of page 52. It is correct the way it is written at the top of page 53. A calorie is defined as the amount of heat energy needed to raise the temperature of one gram of water one degree on the Celsius scale.

B. Energy in Phase Changes

To do: Read Sections 5-2 and 5-3, pages 86-90.

Pure substances can be converted from gas to liquid by a process called phase change. Phase changes are familiar to you; ice melts to water and water boils to give steam or water vapor; solid iron melts to liquid iron; gaseous ammonia condenses to give liquid ammonia; candle wax melts to give liquid wax. These are only a few of the phase changes with which you are familiar.

When a beaker of water is warmed by a burner, the input of energy causes the temperature of the water to rise. At a certain temperature the water begins to boil. Gas bubbles rise to the surface. Liquid water is being converted to gaseous water. If we place a thermometer into the boiling water, we find that the temperature remains constant as the boiling process continues at constant pressure. What then, happens to the energy that is being supplied during boiling? This energy is used to overcome the binding forces between water molecules which results in further separations of water molecules. Energy is continually added until all molecules have reached a new phase - the gas phase, and we can say that evaporation is now complete.

It is quite evident that water in the gas phase has more energy than water in the liquid phase. This can be represented by the following equation $H_2O_{(l)}$ + thermal energy $\longrightarrow H_2O_{(g)}$. Conversely, as steam condenses and changes to liquid, thermal energy is released: $H_2O_{(g)} \longrightarrow H_2O_{(l)}$ + thermal energy. It is possible to determine the actual amount of energy involved by using a device called a calorimeter (see Figure 11-4, page 222 of your textbook). It was found experimentally that it takes 40.8 kJ of energy to vaporize 1 mole of water (6.02×10^{23} molecules or 18.0 g) at 1 atm. pressure and 100°C.

This value, 40.8 kJ , is called the MOLAR HEAT OF VAPORIZATION and is commonly expressed in the equation as follows:

$$H_2O_{(l)} + 40.8 \text{ kJ} \rightarrow H_2O_{(g)}$$

Exercise 1

(1) Calculate the energy required: (Give answers in Joules.)

(a) to evaporate 36 g of water at 100° C and 1 atm.

(b) to evaporate 6.02×10^{22} molecules of water at 100° C and 1 atm.

(c) to evaporate 0.18 g of water at 100° C and 1 atm.

Experimentally it is also possible to determine the amount of energy required to melt one mole of a substance. For example, it was found that it takes 1.44 kcal of energy to melt one mole (18 g) of ice at 0° C and change it to water at 0° C. Note that there is no temperature change during a phase change. This energy required to melt one mole of a substance is called the MOLAR HEAT OF MELTING or FUSION and can be represented by an equation as follows:

$H_2O_{(s)} + 1.44 \text{ kcal} \rightarrow H_2O_{(l)}$ or $H_2O_{(s)} + 6.03 \text{ kJ} \rightarrow H_2O_{(l)}$

Below you will find values for molar heat of melting for other substances.

Substance	Phase Change	Molar Heat of Melting
chlorine	$Cl_{2(s)} \longrightarrow Cl_{2(l)}$	1.53 kcal
sodium	$Na_{(s)} \longrightarrow Na_{(l)}$	0.63 kcal
sodium chloride	$NaCl_{(s)} \longrightarrow NaCl_{(l)}$	6.80 kcal
copper	$Cu_{(s)} \longrightarrow Cu_{(l)}$	3.11 kcal

Exercise 2

(1) Which would likely cause more severe burns, one gram of $H_2O_{(g)}$ at 100° C or one gram of $H_2O_{(l)}$ at 100° C? Why?

_____

_____

(2) How much heat would be required to melt one kilogram of sodium?

(3) How much heat would be required to melt 6.34 g of copper?

(4) Calculate the number of grams of NaCl that can be melted by using 3400 cal of heat. (Assume no heat losses).

(5) Liquids used in rocket fuels are passed over the outer wall of the combustion chamber before being fed into the chamber itself. What advantages does this system offer?

_____

_____

_____

_____

C. Energy in Chemical Reactions

In your study about phase changes you have probably observed that the molecular structure did not change during a phase change. The number of atoms of a given element remains the same regardless what phase it is in. However, in a chemical reaction, although mass is conserved, there is a rearrangement of atoms, with products having entirely different molecular structures than the reactants. Also, much more energy is involved in a chemical reaction than in a phase change. Some of the more common chemical reactions occur when fossil fuels burn in our homes to supply us with heat energy or when fossil fuels burn in the internal combustion engine to supply energy required to operate our automobile. With the ever increasing requirement for fossil fuels, and with the possibility of future energy crisis, a great deal of attention has been given lately to the conservation of our present energy supplies. One good example is that of the recently government sponsored home owners insulation scheme: a plan where homeowners can get government grants to cover the cost of insulating their homes. As our requirements for fossil fuels increase and available supplies diminish, it becomes very important for chemists, physicists, engineers, environmentalists and the general public to cooperate in finding more efficient ways for operating our automobiles, heating our homes and running our industries. Hopefully, by a better understanding of the issues at hand, and with improved technology, we can reduce inefficiency and waste and thereby save some of our precious resources for future generations. It is interesting to note that

recently there has been a keen interest shown in other forms of energy, such as solar, geothermal, tidal, wind, and nuclear, with increasing government grants given to research and experimentation. It may not be too long that solar heated homes will be as common as our gas heated homes of today. It is beyond the scope of this course to delve into this topic of alternate forms of energy, but we will discuss nuclear energy in more detail later on in the course.

Let us now turn our attention to the study of chemical reactions and energy effects known as Chemical Energetics. We will try to answer some of the following questions: How much energy is involved in a chemical reaction? How do we find this out? Where does this energy come from?

To begin answering these questions, let us begin with a practical situation. For instance, a chemical engineer is called upon to design a boiler for a large industrial plant. In order to please the plant manager he must design a boiler that is efficient and economical to use in terms of energy consumption. He must also find a fuel that will give him the most for his money. It is here where the chemical engineer must rely on his knowledge of chemical energetics as will be shown in the next lesson.

At this point we will review some of the basic concepts in order to make the next lesson easier to comprehend.

You will recall from previous study of chemistry that equations involving energy fall into two main categories, (i) endothermic and (ii) exothermic.

In an endothermic reaction, energy is absorbed which may be shown by the following equation:

(a) $2NH_{3(g)} + 22 \text{ kcal} \longrightarrow N_{2(g)} + 3H_{2(g)}$

In other words, the above equation shows that 22 kcal of energy are required to produce 1 mole of nitrogen gas from the compound ammonia.

In an exothermic reaction, energy is released as shown by the equation below:

(b) $H_{2(g)} + \frac{1}{2}O_{2(g)} \longrightarrow H_2O_{(l)} + 68.3 \text{ kcal}$

The equation shows that upon burning one mole of hydrogen gas, 68.3 kcal of energy are released. This energy is sometimes called the Molar Heat of Combustion of hydrogen.

Exercise 3: Note: N_2, H_2 are diatomic elements. Use the correct molar mass of these elements in these questions.

(1) Using Equation (a) above, calculate the heat absorbed when one mole of hydrogen gas is produced.

(2) Calculate the quantity of heat absorbed when 42 g of nitrogen are produced.

(3) Using Equation (b) calculate the heat released when 1 kg of hydrogen burns.

(4) To yield 272 kcal of heat in equation (b), calculate the number of moles of oxygen required.

(5) (a) Which yields more energy: the combustion of one gram of hydrogen, or the condensation of one gram of steam at 100° C?

_____

(b) How much more?

From your previous chemistry course you may recall the experiment on Determining the Heat of Combustion of Candle Wax. (Lesson 5 - Experiment 5 Chem. 20) We will not repeat the experiment here, but we will supply you with some experimental data and ask you to do the related problems. Hopefully this exercise will give you a better understanding of how energy is related to chemical reactions.

Data:

A. Weight of candle burned

	Weight of candle before	34.5 g
minus	Weight of candle after	32.8 g
	Weight of candle burned	_____

B. Weight of Water Heated

Weight of water plus can	408 g
Weight of can	87 g
Weight of water heated	_____

C. Temperature changes of water, Δt

	Temperature of water after heating	44.6°C
minus	Temperature of water before heating	12.4°C
	Δt =	_____

Exercise 4

(1) Ignoring the fact that your container also absorbs heat, and using the above data, calculate the quantity of heat that is required to warm the water. Express your answer in calories. (Note: It takes one calorie of heat to raise the temperature of one gram of water one degree centigrade.) Heat (cal) = mass × temperature change × specific heat. The specific heat for the above solutions may be assumed to be 1 cal/g-deg.

(2) Assuming that all the energy from the burning candle went into heating the water, calculate the energy released per gram of wax.

(3) If wax has the chemical formula $C_{25}H_{52}$, calculate the molar heat of combustion of wax.

(4) List 3 possible factors that may be responsible for experimental error.

(a) _____

(b) _____

(c) _____

(5) Because we did not allow for the heat that was absorbed by the container, explain how this one factor affected the value that you obtained in Question (3).

_____

_____

End of Lesson 4

LESSON RECORD FORM

3240 Chemistry 30

Revised 90/07

FOR STUDENT USE ONLY

Date Lesson Submitted

_____

Time Spent on Lesson

_____

(If label is missing or incorrect)

File Number

_____

Lesson Number _____

FOR SCHOOL USE ONLY

Assigned Teacher: _____

Lesson Grading: _____

Additional Grading E/R/P Code: _____

Mark: _____

Graded by: _____

Assignment Code: _____

Date Lesson Received:

_____

Lesson Recorded _____

Student's Questions and Comments

Apply Lesson Label Here

Name

Address

Postal Code

Please verify that preprinted label is for correct course and lesson.

Teacher's Comments:

_____

Correspondence Teacher

St. Serv. 21-89

ALBERTA CORRESPONDENCE SCHOOL

MAILING INSTRUCTIONS FOR CORRESPONDENCE LESSONS

1. BEFORE MAILING YOUR LESSONS, PLEASE SEE THAT:

(1) All pages are numbered and in order, and no paper clips or staples are used.
(2) All exercises are completed. If not, explain why.
(3) Your work has been re-read to ensure accuracy in spelling and lesson details.
(4) The Lesson Record Form is filled out and the correct lesson label is attached.
(5) This mailing sheet is placed on the lesson.

2. POSTAGE REGULATIONS

Do **not** enclose letters with lessons.

Send all letters in a separate envelope.

3. POSTAGE RATES

First Class

Take your lesson to the Post Office and have it weighed. Attach sufficient postage and a green first-class sticker to the front of the envelope, and seal the envelope. Correspondence lessons will travel faster if first-class postage is used.

Try to mail each lesson as soon as it has been completed.

When you register for correspondence courses, you are expected to send lessons for correction regularly. Avoid sending more than two or three lessons in one subject at the same time.